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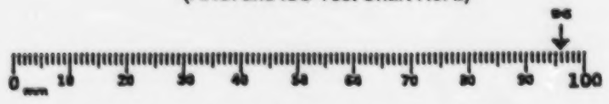


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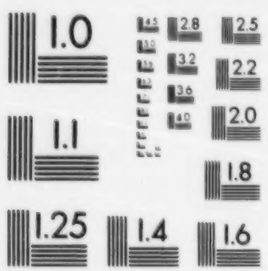


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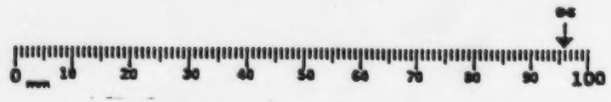


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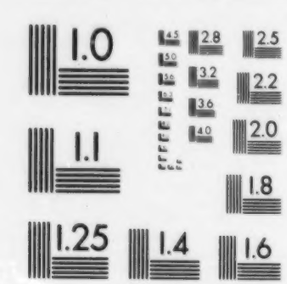


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# Report of the PSARC Herring Subcommittee Meeting September 1-3, 1998 and the Steering Committee Meeting September 15, 1998

M. Stocker and R. Kronlund (Editors)
Pacific Stock Assessment Review Committee (PSARC)
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

September 1998

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**PACIFIC STOCK ASSESSMENT REVIEW COMMITTEE**

**PSARC ADVISORY DOCUMENT 98-5**
**SEPTEMBER 1998**

# PACIFIC HERRING

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## I. STEERING COMMITTEE REPORT

The PSARC Steering Committee met 15 September, 1998 at the Pacific Biological Station to review the Herring Subcommittee report. The Subcommittee report was accepted by the Steering Committee with the following comments and recommendations. The Steering Committee thanked the Subcommittee chair for a useful and well organized report.

Stock Status and Yield Recommendations

The five major herring stocks in B.C. are managed by a fixed harvest rate policy in conjunction with a Cutoff level. Cutoff levels are set at 25% of unfished average biomass. Yield recommendations are set at 20% of forecast annual biomass unless the forecast is close to or below Cutoff levels. Assessments of major stocks are conducted using both age-structured (ASM) and escapement (ESM) models. For several years divergence of results between the ASM and EM have been noted by the Steering Committee.

The Steering Committee noted that the Subcommittee decided to adopt the escapement model forecasts for 1999, rather than assigning equal weight to each model. While the Steering Committee accepted this decision, the Steering Committee strongly endorsed the Subcommittee recommendations to examine the underlying assumptions of the age-structured model and to submit the ASM model to diagnostic tests to resolve the discrepancies between the two models.

The Steering Committee accepts the forecast biomass and yield recommendations for 1999 presented in Table 3 of the Subcommittee report.

Queen Charlotte Islands

The Steering Committee endorsed the recommended yield of 5,642 tonnes based on the assumption of average recruitment.

Prince Rupert District

The Steering Committee endorsed the recommended yield of 4,884 tonnes based on the assumption of average recruitment.

Central Coast

The Steering Committee endorsed the recommended yield of 8,686 tonnes based on the assumption of average recruitment.

Strait of Georgia

The Steering Committee endorsed the recommended yield of 15,780 tonnes based on the assumption of average recruitment.

West Coast Vancouver Island

The Steering Committee endorsed the recommended yield of 7,920 tonnes. The Steering Committee accepted the Subcommittee recommendation of poor recruitment for this stock in 1999. The prediction of poor recruitment is based on a long-term DFO research program which has demonstrated that herring recruitment tends to be poor when ocean temperatures are warm and the summer biomass of predators is high during the first year of life. Warm temperatures and high predator biomass were the prevailing conditions in 1996.

The Steering Committee notes that, given the potential distribution of the spawn in this area (i.e. Hesquiat), the recommended yield of 7,920 t may be operationally difficult to achieve.

Minor Stocks

The Steering Committee endorsed the recommended yield of 200 tonnes for Area 27 computed as 10 % of the assessed 1998 abundance, and no surplus in Area 2W.

Comments on Working Papers

**H98-1 Stock assessments for British Columbia herring in 1998 and forecasts of the potential catch in 1999.**

The Steering Committee accepts the working paper recommendations on revisions and strongly urged that the review recommendations regarding the age-structured model be addressed prior to the next assessment.

**H98-2 An evaluation of the natural mortality rate used in the assessment of British Columbia herring stocks.**

The Steering Committee accepted and endorsed the recommendations of the Subcommittee.

**H98-3 Variations in size-at-age of British Columbia stocks of Pacific herring (*Clupea pallasi*) and its implications for quota recommendations and fisheries management.**

The Steering Committee accepted and endorsed the recommendations of the Subcommittee.

**H98-4 Offshore herring distribution and the 1999 recruitment forecast for the west coast of Vancouver Island stock assessment region.**

The Steering Committee accepted and endorsed the recommendations of the Subcommittee.

**H98-5 Distribution and timing of herring spawning in British Columbia.**

The Steering Committee accepted and endorsed the recommendations of the Subcommittee. The Steering Committee recommends that the fine scale population structure of herring be resolved.

Comments on the General Subcommittee Recommendations for 1998

The Steering Committee endorsed the general recommendations made by the Subcommittee with the following comments:

1. The Steering Committee recommends strongly that the issues raised in Subcommittee recommendation #1 be resolved.

2. The Steering Committee reiterated its recommendation that explicit statements of uncertainty and risk of falling below Cutoff biomass levels be incorporated into herring assessment.

3. The Steering Committee endorsed Subcommittee recommendation #6 which stated that improved forecasting of recruitment processes is a high priority.

## II. HERRING SUBCOMMITTEE REPORT

### 1. PSARC Herring Subcommittee Objectives

The Subcommittee met on September 1-3, 1998 to review the status of herring stocks in 1998 and to forecast abundance and potential yield for 1999. The Subcommittee reviewed five working papers (Appendix 1) and evaluated the impacts of pertinent assessment criteria (Appendices 3-7) in the formulation of advice to fisheries managers. The Subcommittee provided recommendations specific to the working papers in addition to general recommendations for further assessment work in support of management. Working paper titles, authors, and reviewers are listed in Appendix 1. A list of meeting participants is included as Appendix 2.

The Subcommittee evaluated a set of assessment indicators for each of the five major assessment regions. These criteria include:

- *Data quality*: catch data, spawn survey adequacy, consistency in age composition data;
- *Spawn and stock trends*: age-structured model and escapement model biomass estimates, spawn indices, in-season acoustic estimates;
- *Perception of stock status*: based on charter skipper and district staff field observations;
- *Recruitment trends*: age-structured model estimates, auxiliary survey data;
- *Cutoff*: minimum spawning biomass level for stock conservation;

- *Forecast abundance (run size)*: weighting for age-structured and escapement models, and evaluation of recruitment assumptions;
- *Additional information*: e.g. independent predictions of recruitment.

Subcommittee review of the assessment documents, in conjunction with the assessment criteria, was used to draw conclusions about the current biological status of the stocks and to provide yield recommendations for harvest in 1999. The following abbreviations are used throughout the Subcommittee Report:

| | |
|---|---|
| ASM | Age-structured model |
| EM | Escapement model |
| CC | Central Coast |
| FSC | Food, Social, Ceremonial |
| HCRS | Herring Conservation Research Society |
| PR | Prince Rupert District |
| QCI | Queen Charlotte Islands |
| SG | Strait of Georgia |
| WCVI | West Coast Vancouver Island |

## 2. Management Strategy

### Major Stocks

Five major British Columbia herring stocks are currently managed by a fixed harvest rate strategy in conjunction with a fishing threshold or "Cutoff" level. Recommended yields are set at 20% of the forecast biomass for each of the major assessment regions, provided that the recommended yield does not reduce the biomass below the Cutoff. The 20% harvest rate is considered to represent a conservative level of removals given the biological productivity of the major herring stocks. Cutoff levels are set at 25% of the estimated unfished average biomass, as determined by simulation analyses. As the forecast abundance approaches the Cutoff, the recommended yield is the difference between the forecast abundance and the Cutoff. When the forecast falls below the Cutoff, a decision may be made to close the fishery to rebuild the stock. The objective of a Cutoff is to prevent relatively large fishery removals on stocks at low levels of abundance. This harvest strategy has been in place since 1983, prior to which the fishery was managed through a fixed escapement policy. A recent review (PSARC Working Paper H95-02) concluded that "... *the current management policy provides an adequate level of protection to conserve the stocks from a fishery collapse, and generates high long-term yields.*"

A summary of the performance of the forecasting procedure for 1998 herring fisheries is shown in Table 1, which compares the 1997 forecast of abundance in each stock assessment region to observed biomass in 1998 based on spawn surveys, catch, and model estimates. Note that with the exception of hailed catch, all numbers were rounded to the nearest 100 tonnes after the requisite calculations.

**Table 1** Comparison of 1997 PSARC forecasts of 1998 herring abundance with estimates of 1998 observed biomass, catch, and escapement (tonnes). The recruitment assumption that generated the forecast biomass (poor, average, good) and the observed recruitment category are shown in brackets. All numbers rounded to the nearest 100 tonnes (except hailed catch).

| Management Region | 1997 Forecast of 1998 Biomass | 1998 Observed Biomass | 1998 Hailed Catch | 1998 Escapement |
|---|---|---|---|---|
| Queen Charlotte Islands | 19,800 (average) | 29,500 (good) | 1,400 | 28,200 |
| Prince Rupert | 34,000 (average) | 20,000 (average) | 3,200 | 16,700 |
| Central Coast | 44,500 (average) | 42,000 (good) | 8,600 | 33,500 |
| Strait of Georgia | 72,700 (average) | 72,100 (average) | 13,600 | 58,500 |
| West Coast Vancouver Island | 40,100 (poor) | 39,000 (poor) | 7,000 | 32,000 |
| Totals | 211,100 | 202,700 | 33,800 | 168,900 |

**Minor Stocks**

There are small or "minor" herring stocks that exist outside the five major stock assessment regions. The minor stocks are assessed opportunistically due to their inaccessibility, so the data series is neither continuous nor extensive. In its 1993 report, the PSARC Herring Subcommittee advised that there is no basis for fishing minor stocks above the 20% harvest rate established for the major stocks, and that DFO should also protect a minimum spawning biomass for the minor stocks.

At the 1994 PSARC Herring meeting, the Subcommittee recommended that because of incomplete historic data, minor stock harvests should be based on the estimated biomass of spawners in the previous season. Consequently, the Subcommittee recommended that the maximum biomass of fish harvested should not exceed 10% of the estimated previous season biomass. The recommended harvest rate for minor stocks is more conservative than the rate adopted for the major stocks; it is intended to compensate for the fact that minor stock survival and recruitment levels cannot be reliably predicted. The data do not allow accurate estimation of minor stock Cutoff levels. The Subcommittee advised that DFO should review biomass levels in light of available historic information

prior to allocating minor stock harvests to clients. It noted that some minor stocks exhibit large fluctuations in abundance, therefore, the opportunity for harvest may not be available every year.

### 3. Catch Trends

Herring in British Columbia waters have supported some form of commercial fishery since 1877. Reliable records of place, date, and quantity caught are available since 1950. A fishery for a dry salted market from 1904 to 1934 (with catches up to 85,000 tonnes annually) was followed by a reduction fishery (1935 to 1967). During the reduction fishery catches were taken during the inshore spawning migrations from October to February. Very large catches (200,000 tonnes annually) in the early 1960s, in conjunction with a series of poor recruitments, led to the collapse of the reduction fishery and subsequent closure in 1968. Cessation of the intensive reduction fishery allowed a gradual recovery of stocks. The roe herring fishery began in 1972. Herring are now caught on or near the spawning grounds by both purse seines and gillnets.

In 1998, there were 252 seine licenses, and 1327 gillnet licenses. Of these, 239 seine licenses and 740 gillnet licenses were eligible to fish. The difference can be attributed to inactivation of a number of licenses for double-licensed gillnet fisheries in Prince Rupert and the Strait of Georgia, test fishing vessels, AFS purchases, and for spawn-on-kelp trade operations. Total roe landings have averaged 29,900 tonnes from 1994 to 1998. Prior to processing, the total landed value of the 1997 commercial roe herring catch of 31,300 tonnes was $30 million. The 1997 spawn-on-kelp fishery landings of 300 tonnes was valued at $10 million.

Coast-wide pool fisheries for seines were implemented in 1998 as a method of reducing catch overages. Pools were organized into groups with a minimum of 8 licenses, and all licenses shared equally in the seine catch (up to the quota) for the area they elected to fish. Gillnet pool fisheries were tried on an experimental basis in Esperanza Inlet (WCVI), Barkley Sound (WCVI), and the Central Coast. Gillnet pools were organized into groups of 4 licenses, and each pool shared the catch for their pool only. Generally speaking, the pool fisheries were well received by industry.

The roe fishery first came under quota regulations in 1983. Prior to this, guidelines of anticipated roe catches were provided. The PSARC recommended yield, actual quota in the roe fishery, and roe catches (thousands of tonnes) since 1983 are listed in Table 2.

**Table 2** Stock biomass forecast, recommended yield, actual roe fishery quota, and roe catches (tonnes x 1000) since 1983.

| | | 1983[e] | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998[d] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QCI[f] | Forecast[a] | | | | | 15.3 | 12.1 | 13.7 | 35.3 | 23.2 | 18.1 | 17.7 | 12.4 | 7.7 | 6.7 | 11.0 | 19.8 |
| | Rec. Yield[b] | | | | | 2.2 | 0.0 | 2.7 | 7.1 | 4.6 | 3.6 | 3.5 | 1.0 | 0.0 | 0.0 | 0.3 | 4.0 |
| | Roe Quota | | 4.6 | 5.0 | 3.8 | 1.4 | 0.0 | 0.9 | 5.5 | 4.7 | 3.3 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.4 |
| | Roe Catch[c] | 8.1 | 5.0 | 6.3 | 3.6 | 2.0 | 0.3 | 1.4 | 9.0 | 7.0 | 3.8 | 4.0 | 0.3 | 0.0 | 0.0 | 0.0 | 1.4 |
| PR | Forecast[a] | | | | | 32.1 | 43.8 | 42.6 | 23.3 | 19.4 | 30.5 | 55.1 | 34.1 | 21.9 | 21.2 | 36.1 | 34.0 |
| | Rec. Yield[b] | | | | | 6.4 | 8.7 | 8.5 | 4.7 | 3.9 | 6.1 | 11.0 | 6.8 | 4.4 | 4.2 | 7.2 | 6.8 |
| | Roe Quota | | 4.0 | 5.0 | 6.4 | 5.4 | 7.5 | 7.3 | 3.5 | 2.6 | 4.2 | 5.4 | 4.9 | 2.3 | 2.4 | 5.5 | 5.3 |
| | Roe Catch[c] | 0.0 | 3.5 | 6.5 | 8.3 | 6.1 | 7.9 | 8.5 | 4.9 | 3.5 | 5.0 | 6.3 | 4.7 | 2.1 | 3.1 | 5.5 | 3.2 |
| CC | Forecast[a] | | | | | 23.0 | 23.8 | 48.5 | 43.2 | 38.2 | 37.7 | 70.1 | 69.8 | 54.4 | 25.8 | 20.7 | 44.5 |
| | Rec. Yield[b] | | | | | 4.6 | 4.8 | 9.7 | 8.6 | 7.6 | 7.5 | 14.0 | 14.0 | 10.9 | 5.2 | 3.1 | 8.9 |
| | Roe Quota | | 6.6 | 4.1 | 2.3 | 3.3 | 3.7 | 7.8 | 7.4 | 6.2 | 5.3 | 7.8 | 10.3 | 8.5 | 3.2 | 1.4 | 7.2 |
| | Roe Catch[c] | 5.7 | 7.2 | 5.2 | 3.3 | 3.6 | 4.5 | 9.5 | 8.4 | 8.9 | 8.3 | 10.5 | 11.9 | 9.6 | 4.3 | 3.6 | 8.6 |
| SG | Forecast[a] | | | | | 53.0 | 46.7 | 49.4 | 55.2 | 69.8 | 59.2 | 91.8 | 97.4 | 69.5 | 63.4 | 77.2 | 72.7 |
| | Rec. Yield[b] | | | | | 10.6 | 9.3 | 9.9 | 11.0 | 14.0 | 11.8 | 18.3 | 19.5 | 13.9 | 12.7 | 15.5 | 14.5 |
| | Roe Quota | 11.7 | 11.6 | 4.7 | 0.0 | 8.0 | 6.4 | 7.4 | 7.1 | 9.1 | 9.7 | 11.0 | 14.4 | 11.9 | 10.8 | 13.2 | 12.2 |
| | Roe Catch[c] | 16.4 | 10.2 | 6.2 | 0.2 | 9.1 | 7.5 | 7.4 | 7.9 | 10.6 | 12.5 | 13.1 | 16.7 | 12.5 | 13.6 | 15.4 | 12.7 |
| WCVI[g] | Forecast[a] | | | | | 48.3 | 39.6 | 52.6 | 35.9 | 33.9 | 29.1 | NA[n] | 36.3 | 20.8 | 21.4 | 24.1 | 40.1 |
| | Rec. Yield[b] | | | | | 9.7 | 7.9 | 10.5 | 7.2 | 6.8 | 5.8 | 3.4[h] | 7.3 | 2.0 | 2.0 | 4.8 | 8.0 |
| | Roe Quota | 4.5 | 4.5 | | 0.0 | 9.4 | 8.1 | 10.3 | 7.2 | 6.7 | 2.9 | 2.7 | 5.0 | 1.3 | 0.9 | 3.7 | 6.9 |
| | Roe Catch[c] | 8.7 | 6.7 | 0.2 | 0.2 | 15.9 | 9.7 | 13.4 | 9.9 | 8.6 | 3.7 | 5.6 | 6.0 | 2.0 | 0.8 | 6.7 | 7.0 |
| Coast | Forecast | 0.0 | 0.0 | 0.0 | 0.0 | 171.7 | 166.0 | 206.8 | 192.9 | 184.5 | 174.6 | 234.7 | 250.0 | 174.3 | 138.5 | 169.1 | 211.1 |
| | Rec. Yield | 0.0 | 0.0 | 0.0 | 0.0 | 33.5 | 30.7 | 41.3 | 38.6 | 36.9 | 34.8 | 50.2 | 48.6 | 31.2 | 24.1 | 30.9 | 42.2 |
| | Roe Quota | 16.2 | 31.3 | 18.8 | 12.5 | 27.5 | 25.7 | 33.7 | 30.7 | 29.3 | 25.4 | 29.9 | 34.6 | 24.0 | 17.3 | 23.8 | 33.0 |
| | Roe Catch | 38.9 | 32.6 | 24.4 | 15.6 | 36.7 | 29.9 | 40.2 | 40.1 | 38.6 | 33.3 | 39.5 | 39.6 | 26.1 | 21.8 | 31.1 | 30.9 |

[a] PSARC stock forecast used to derive recommended yield;
[b] PSARC recommended yield, includes allocations to non-roe fisheries;
[c] Roe catch includes all test fishery catches;
[d] Catch in 1998 was the hailed catch;
[e] In 1983, the quota for North of Cape Caution was 11.8 tonnes;
[f] In 1983, 1985, 1990, 1991, 1992 and 1993 catch for QCI included both areas 2E and 2W;
[g] Includes Area 27 catch in 1983 & 1984 but excludes it in 1992, 1993, 1994, 1995 following removal from assessment regio
[n] No consensus on stock status, recommended that catch not exceed 1992 level.

## 4. Stock Status and Forecasts for Major Assessment Regions

### Management Regions for Major Stocks

The stock assessment regions for major herring stocks are shown in Figure 1. For northern British Columbia, the stock assessment regions used for the 1998 assessments are the same as those used in previous years. In the Queen Charlotte Islands (QCI), the assessment region extends from Cumshewa Inlet in the north to Louscoone Inlet in the south. The Prince Rupert District (PR) stock assessment region includes all of Statistical Areas 3 to 5. The Central Coast (CC) assessment region encompasses Area 7, Kitasu Bay in Area 6, and Kwakshua Channel in Area 8. As recommended by the Herring PSARC Subcommittee in 1991, the Strait of Georgia (SG) is considered a single stock complex which includes Deepwater Bay and Okisollo Channel in Area 13 and all of Areas 14 to 19, 28 and 29. In 1993, the northern (Area 25) and southern (Area 23/24) Statistical Areas were combined into the West Coast Vancouver Island (WCVI) assessment region.

### Stock Assessment

Two analytic models, an age-structured model (ASM) and an escapement model (EM), are applied to each management region. Generally, an overall estimate of stock abundance in the current year, and a forecast abundance for the next fishing year, are obtained by combining the estimates from each model. The assigned weighting is dependent on review of the adequacy and performance of each of the models. In recent years, the two models have been weighted equally unless there was information to suggest that one of the models did not provide consistent stock estimates (*e.g.* the age-structured model performs poorly for the Prince Rupert District, as described below). However, the Subcommittee departed from this practice in 1998 when it adopted the escapement model forecasts.

At the direction of Steering Committee, the Subcommittee has examined the discrepancy between the ASM and EM for several years. After consideration of the divergence of results between the ASM and EM, and the factors that could bias the ASM, the Subcommittee decided to adopt the escapement model forecasts for 1999 rather than assigning equal weight to each model. The reviews and Subcommittee discussion highlighted the need to submit the ASM to diagnostic tests with respect to the interaction of the natural mortality parameter with other model parameters. Additional scrutiny of temporal trends in assessment variables is warranted in light of the marked decline in size-at-age of B.C. herring stocks (Working Paper H98-3). The assumption that the tuning index is proportional to stock biomass requires validation, potentially through the use of a Virtual Population Analysis (VPA) model. Furthermore, the plausibility of fish movement or temporal variation in maturity schedules requires investigation. These hypotheses may help to explain the highly variable estimates of natural mortality among assessment regions. The Subcommittee emphasized that age-structured modelling was not rejected as a stock assessment tool for herring. Rather, the Subcommittee decided that the ASM forecasts should not be used until the review recommendations are addressed.

The potential recruitment of age 2+ fish to each stock is calculated as the mean of the top one-third, middle one-third and bottom one-third of the average of the recruitment estimates from the two models for the 1951 to 1998 time series. In the absence of additional information to forecast recruitment, the average recruitment forecast is used. Recruitment is added to the expected age 3+ and older abundance to obtain the forecast abundance. The recommended yield is 20% of the weighted, forecast abundance. If this yield would reduce the escapement biomass of a stock below the Cutoff, the recommended yield is calculated from the following equation:

Yield=Weighted forecast - Cutoff

Thus, progressively smaller fisheries are recommended when a stock approaches its Cutoff level. The Cutoff is calculated independently for each stock assessment region.

An example of yield calculations for three levels of forecast biomass is shown in Figure 2. The Cutoff for this example is set at 10,000 tonnes (dashed vertical lines). The upper panel shows catch (tonnes) as a function of the forecast biomass, while the lower panel shows harvest rate as a function of the forecast biomass. There are three scenarios denoted by A, B, and C on the figure panels:

(A) The forecast biomass of 7,500 tonnes is below the Cutoff, so the recommended yield is 0, and the harvest rate is 0.

(B) If the 20 percent harvest rate was applied, the forecast biomass of 11,000 tonnes would yield 0.2*11,000=2,200 tonnes. However, this yield would bring the stock size below the Cutoff value to 11,000-2,200=8,800 tonnes. Thus, the recommended yield is 11,000-10,000=1,000 tonnes. This is equivalent to a harvest rate of 1,000/11,000=0.09, a value roughly half that of the rate of 0.2 used at higher levels of biomass.

(C) The forecast biomass of 20,000 tonnes is well above the Cutoff, so the recommended yield is 0.2*20,000=4,000 tonnes.

Recommended Coast-Wide Yield for 1999

The recruitment assumption, corresponding 1999 pre-fishery biomass forecast, and the recommended yield for each of the major stock regions are listed in Table 3. The spawning stock biomass trends based on the age-structured model (ASM) and escapement model (EM) are shown in Figure 3 and Figure 4. These trends were interpreted in light of the assessment criteria listed in Appendices 3-7 for each management region to determine the recommended yield. Regional synopses are provided below. The Subcommittee noted that the total recommended yield of approximately 42,910 tonnes for 1999 is a 2 percent increase from the total recommended yield of 42,220 tonnes in 1998.

**Table 3** Recommended Yield in 1999 for Major Herring Stocks

| Assessment Region | Cutoff Biomass (tonnes) | Recruitment Assumption | Forecast Biomass (tonnes) | Recommended Yield (tonnes) |
|---|---|---|---|---|
| Queen Charlotte Islands | 10,700 | Average | 28,210 | 5,642 |
| Prince Rupert District | 12,100 | Average | 24,420 | 4,884 |
| Central Coast | 17,600 | Average | 43,430 | 8,686 |
| Strait of Georgia | 21,200 | Average | 78,900 | 15,780 |
| West Coast Vancouver Island | 18,800 | Poor | 39,600 | 7,920 |
| Total | | | 214,560 | 42,912 |

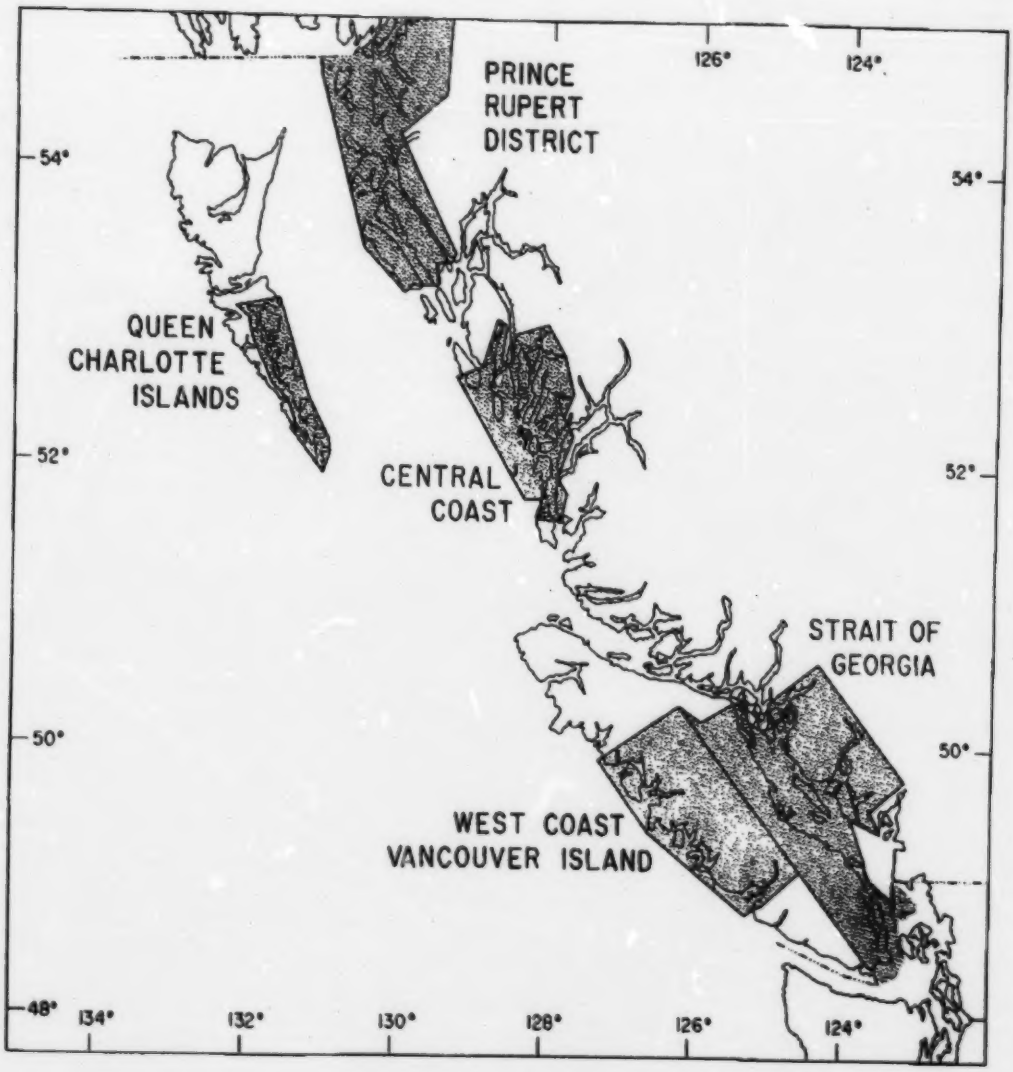


**Figure 1.** Herring stock assessment regions in British Columbia.

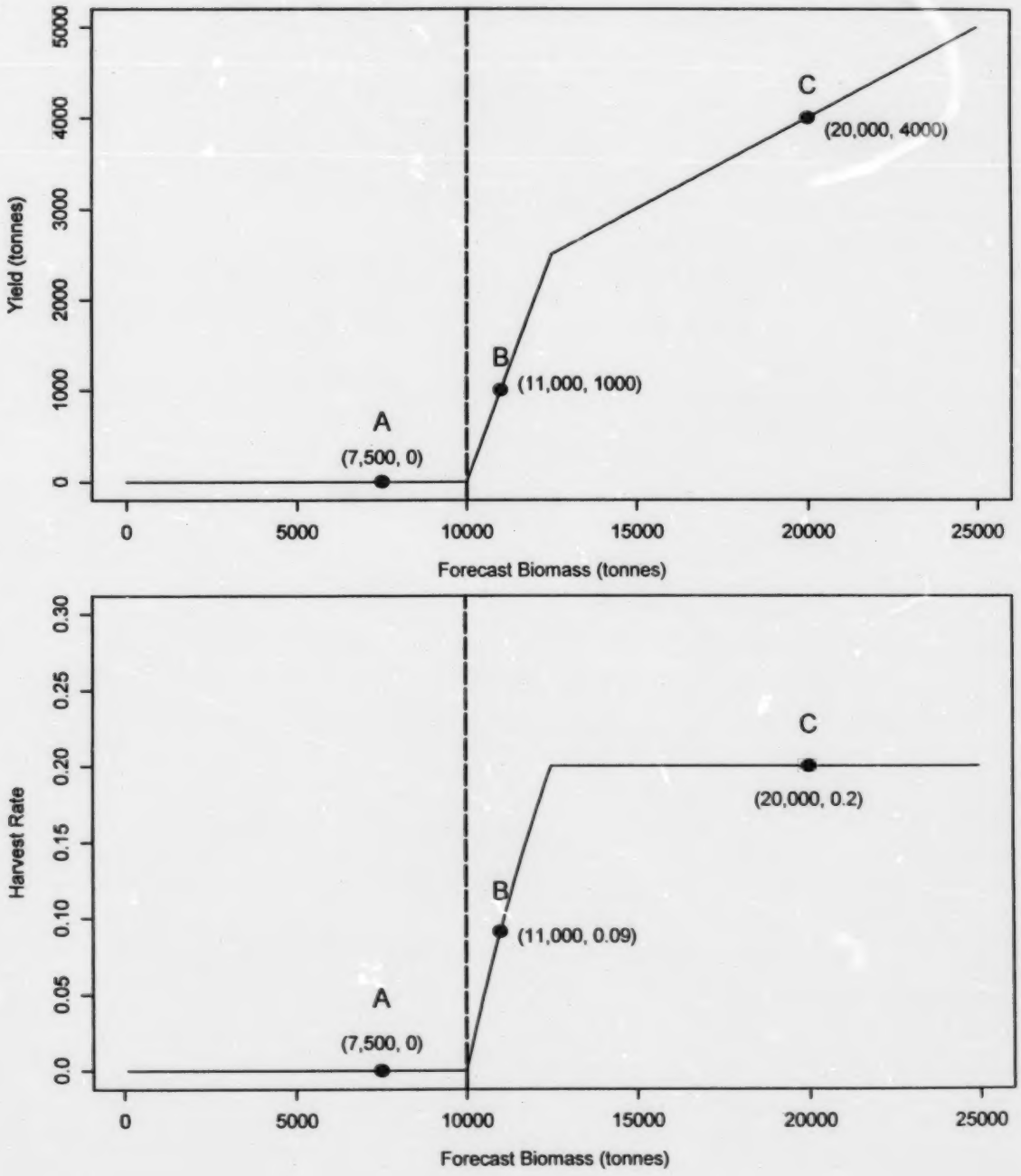


**Figure 2.** Examples of yield and harvest rate at three different levels of forecast biomass. The letters A, B, and C denote three harvest scenarios as described in the text.

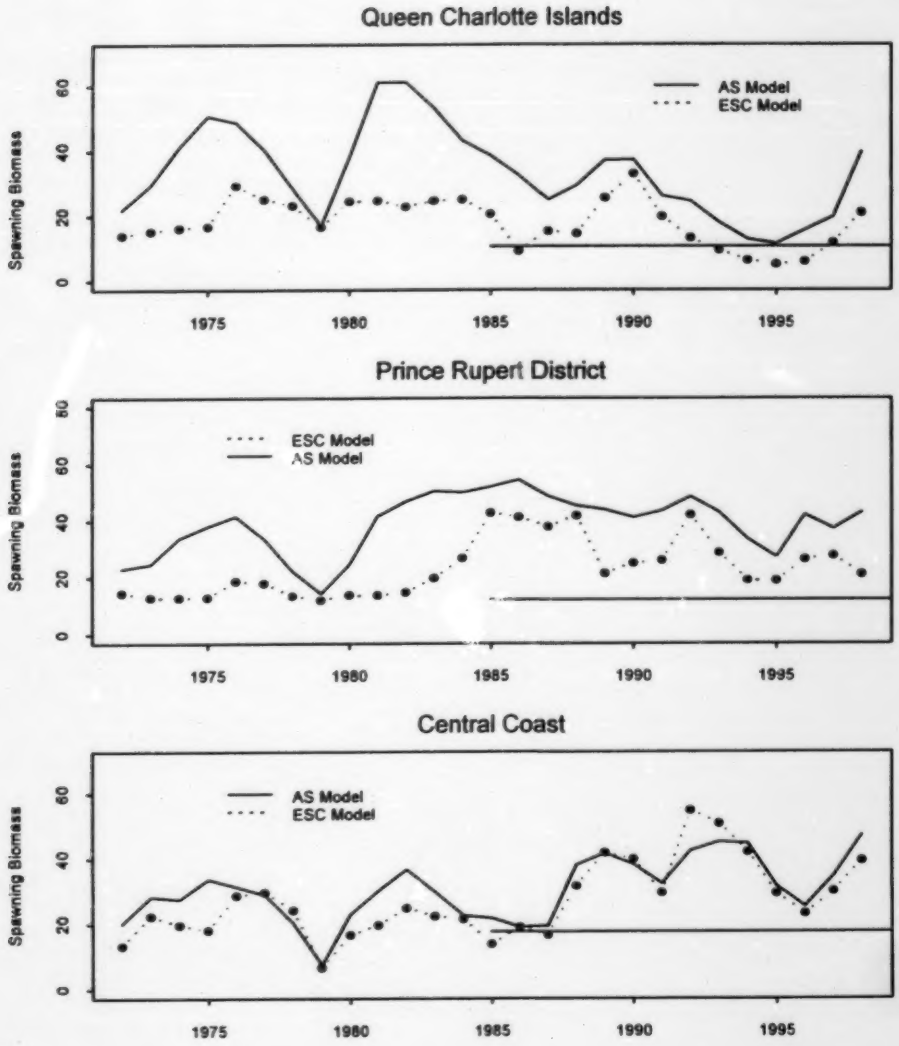


**Figure 3.** Estimates of pre-fishery spawning stock biomass (tonnes x 1000) from age-structured and escapement model analyses for northern B.C. herring stock assessment regions, 1972-1998. The solid horizontal line indicates the Cutoff level.

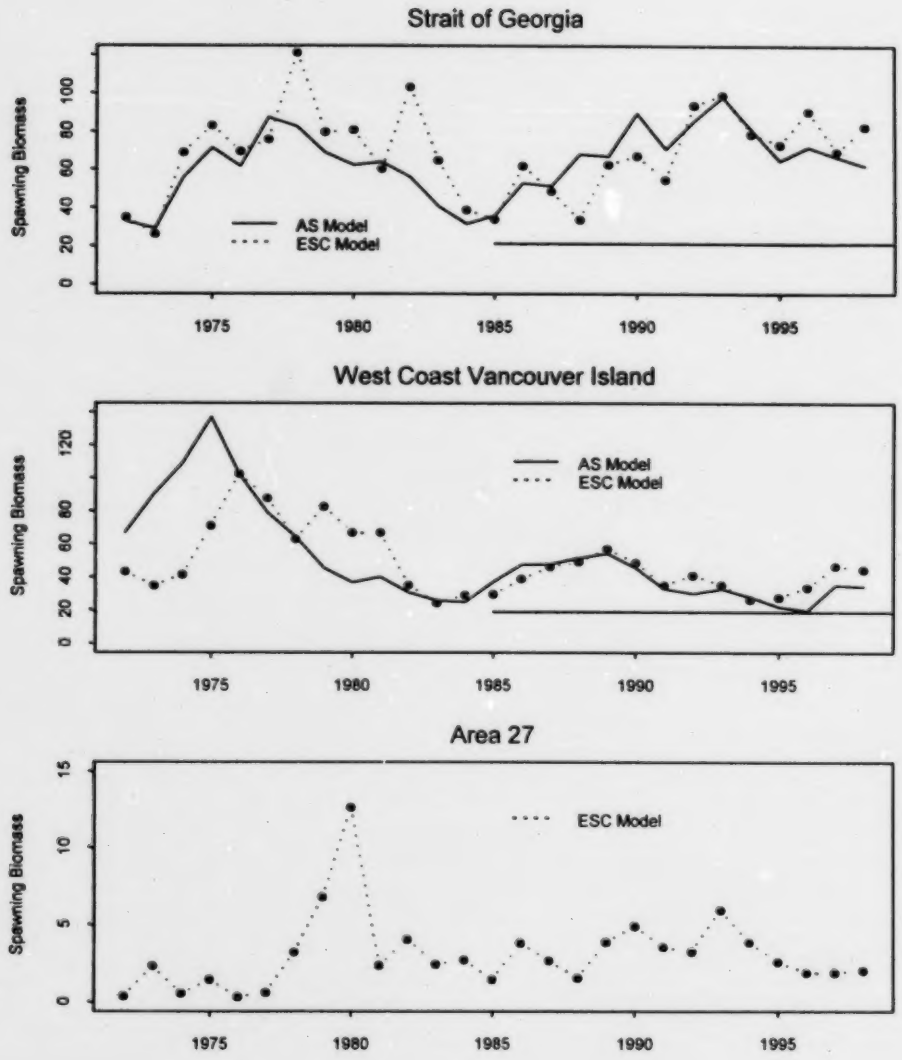


**Figure 4.** Estimates of pre-fishery spawning stock biomass (tonnes x 1000) from age-structured and escapement model analyses for southern B.C. herring stock assessment regions and Area 27, 1972-1998. The solid horizontal line indicates the Cutoff level.

Queen Charlotte Islands

*Background*

Landings during the reduction fishery period (1951 to 1968) were highly variable, targeting on a few strong year classes. The maximum catch taken during this period was over 77,000 tonnes, however, there were 6 years when catches were less than 1,000 tonnes. Catches have been more stable since the beginning of the roe fishery and have generally been in the range of 4,000 to 8,000 tonnes. The area was closed to roe herring fisheries in 1988 due to stock concerns. The stock recovered after the closure but declined from 1990 to 1995. In response to the observed decline, annual roe fishery catches were reduced from 7,800 tonnes in 1990 to 2,700 tonnes in 1993. In 1994, the forecast return was close to Cutoff, and fishing was restricted to Food, Social and Ceremonial (FSC) harvest and spawn-on-kelp only. For 1995 and 1996, the forecast abundance was below Cutoff so fishing was limited to FSC harvest only. In 1997, FSC harvest was permitted, and three spawn and kelp operators used a maximum of 150 tonnes of herring to obtain their quota. The roe fishery was re-opened in 1998, with a harvest of 1,400 tonnes.

*Assessment Criteria*

No FSC catch has been reported from the Queen Charlotte Islands in 1998. In-season stock sampling and spawn assessment programs were carried out in a manner consistent with other assessment areas, with the exception of an incomplete survey in area 2W. In general, the level of biological sampling was adequate and all major spawns were covered by dive survey. However, late spawn occurring subsequent to the termination of the survey contract was missed.

Both the age-structured and escapement models indicate a decline in abundance from 1990 to 1995, with an increasing trend from 1996 through 1998. The declining stock trend observed between 1990 and 1995 resulted from a series of years with poor recruitment. Increase in biomass since 1995 resulted from greater than average recruitment of the 1993 and 1994 years classes. The 1994 and 1995 year classes now account for 28 and 53 percent of the stock, respectively.

The local fishery manager noted that stocks were improved, with spawns more numerous but smaller than previous years. A 30 percent increase in stock size was estimated along with smaller size-at-age. The charter skipper considered the Queen Charlotte Islands to be improved, and also noted small size-at-age fish. Peak sounded tonnage was 8,300 tons, down from 12,500 tons in 1997.

In the absence of additional information, the Subcommittee adopted an average recruitment assumption in forecasting the QCI stock in 1999. Under this assumption, the ASM forecast of abundance was 40,830 tonnes, while the EM forecast was 28,210 tonnes. The Subcommittee noted that the retrospective analysis suggests the ASM tends to over-forecast abundance, and discussed possible sampling bias in northern regions. The estimated natural mortality was credible at 0.45, however, the ASM results assigned 50 percent more spawn to the assessment region than indicated by the EM. Although the

EM is believed to produce conservative forecasts, the Subcommittee considered the results of the ASM to be unlikely. The Subcommittee adopted the escapement model assuming the average recruitment scenario. The pre-fishery forecast of 28,210 tonnes in 1999 is well above the Cutoff of 10,700 tonnes. Application of the 20 percent harvest rate to the forecast resulted in a recommended yield of 5,642 tonnes.

Prince Rupert

*Background*

During the period of the reduction fisheries, herring catches in the Prince Rupert District were generally in the range of 10,000 to 50,000 tonnes annually. Since the beginning of the roe herring fishery, catches have averaged 5,000 tonnes and have not exceeded 9,000 tonnes. Since 1972, the fishery was closed only in 1983. The area has supported substantial roe herring and spawn-on-kelp fisheries in recent years. However, there was no seine fishery carried out in the traditional location (Kitkatla Inlet) from 1996 to 1998 due to the low biomass of spawners in recent years. A substantial improvement in spawning was noted in Kitkatla in 1998, which may provide for seine fishing opportunities in the next few years.

*Assessment Criteria*

The quality of assessment data in 1998 was adequate. The trend in spawn from the ASM and EM do not agree. Comments from fishery managers and charter skippers in 1998 indicate that returns to Kitkatla had improved relative to recent returns. The charter skippers thought that Area 3 and 4 stocks were down considerably from last year.

The age-structured model indicated an increase in abundance in 1998, while the escapement model indicated a decline. The declining stock trend observed between 1990 and 1995 resulted from a series of years with poor recruitment. Increase in biomass since 1995 resulted from greater than average recruitment of the 1993 and 1994 year classes. These year classes now account for 36 and 22 percent of the stock, while the recruiting 1995 year class adds an estimated 33 percent to the run.

In the absence of additional information, the Subcommittee adopted an average recruitment assumption in forecasting the PR stock in 1999. Under this assumption, the ASM forecast of abundance was 41,820 tonnes, while the EM forecast was 24,420 tonnes. The Subcommittee agreed that more realistic estimates of biomass had been achieved in the 1998 assessment using the ASM after removal of the fall food fishery samples from the input data. However, the Subcommittee noted that the past retrospective analysis suggested the ASM tends to badly over-forecast abundance, and that no retrospective analysis had been conducted following the removal of the fall food fishery data in 1998. The estimated natural mortality was high at 0.52. As with the QCI region, the ASM results assigned at least 50 percent more spawn to the assessment region than indicated by the EM. Although the EM is believed to produce conservative forecasts, the Subcommittee considered the results of the ASM to be unlikely. The Subcommittee adopted the escapement model assuming the average recruitment scenario. The pre-fishery forecast of 24,420 tonnes in 1999 is well above the Cutoff of

12,100 tonnes. Application of the 20 percent harvest rate to the forecast resulted in a recommended yield of 4,884 tonnes.

Central Coast

*Background*

Landings during the reduction fishery period (1950-1968) ranged to just over 44,000 tonnes and were generally around 10,000 to 35,000 tonnes. During the subsequent roe fishery period (1972 to present), landings have averaged 7,145 tonnes and reached a maximum of 14,000 tonnes in 1978. No harvest was permitted in the Central Coast in 1979, but fisheries have occurred annually since that time. Harvests were approximately 10,000 tonnes from 1993 to 1995, then were reduced to 3,200 tonnes in 1996 in response to declining abundance. Abundance has increased dramatically over the past two years as a result of improved recruitment.

*Assessment Criteria*

Abundance trends provided by the two assessment models agreed closely and indicated a recent increase in stock abundance from the recent low in 1996. A good recruitment to the stock occurred in 1997 (1994 year class), following four years of poor to average recruitment. The 1994 and 1995 year classes now account for 42 and 36 percent of the stock, respectively.

The quality of assessment data collected in 1998 is considered to be good, however, FSC catch remains unreported from the Central Coast region. The use of dive spawn surveys has been expanded to cover all spawns in the assessment area. The spawn indices are high and peak sounded tonnage in 1998 was 43,000 tons. Charter skippers perceived healthy stocks, although down somewhat from the 1997 abundance. Local management staff concluded stocks were healthy with spawning occurring in more areas than in recent years.

In the absence of additional information, the Subcommittee adopted an average recruitment assumption in forecasting the CC stock in 1999. Under this assumption, the ASM forecast of abundance was 47,540 tonnes, while the EM forecast was 43,430 tonnes. The Subcommittee noted that the retrospective analysis suggests the ASM tends to over-forecast abundance, and noted the potential for sampling bias in northern regions. The estimated natural mortality was very low relative to the other assessment regions at 0.27. When M is fixed at more likely values of 0.4 to 0.45, the ASM biomass trajectory is much higher than the corresponding trajectory for the EM (see H98-2). The Subcommittee adopted the escapement model assuming the average recruitment scenario. The pre-fishery forecast of 43,430 tonnes in 1999 is well above the Cutoff of 17,600 tonnes. Application of the 20 percent harvest rate to the forecast resulted in a recommended yield of 8,686 tonnes.

Strait of Georgia

*Background*

Annual herring landings from the Strait of Georgia during the reduction fishery period (1951 to 1968) were less variable than from other areas of the coast. With the exception of the 1952/53 season when industry disputes curtailed the herring fishery, and the 1967/68 season when stocks had collapsed, landings ranged from 31,000 tonnes (1966/67) to 72,000 tonnes (1955/56). During the period of roe herring fisheries, catches have averaged 11,600 tonnes. The area was closed to roe herring fishing in 1986, after which time harvests have increased to a peak of 16,304 tonnes in 1997 and a catch of 13,604 tonnes in 1998.

The high catches in the 1990's have been supported by near record high stock abundance in the Strait of Georgia. The two assessment models indicated a decline in abundance from about 90,000 tonnes in 1993 to 72,000 tonnes in 1998. The stock has been supported by average or better recruitment in 8 of the last 10 years, with the most recent recruiting year class (1995 year class) appearing to be of average to good size. The recruiting 1995 year class contributed 33 percent of the stock in 1998.

*Assessment Criteria*

No winter food and bait fishery catch has been reported although FSC catch is reported. All major spawns were surveyed in 1998. Charter skippers commented that stocks were impressive, but the fish were of small size. The peak sounding was estimated at 117,000 tons. Local managers concluded that the SG continues to show very strong returns with spawning spread throughout the region. Managers agreed that the size of fish had declined.

In the absence of additional information, the Subcommittee adopted an average recruitment assumption in forecasting the SG stock in 1999. Under this assumption, the ASM forecast of abundance was 59,320 tonnes, while the EM forecast was 78,900 tonnes. The Subcommittee noted that the retrospective analysis results were mixed for this assessment region. The potential for sampling bias was not judged to be significant for the SG. The estimated natural mortality was very high at 0.59, although fixing the value of M at 0.4 to 0.45 did not change the biomass trajectory significantly. The Subcommittee noted that all stock indicators were increasing for the SG and that the stock was near historic high levels. The Subcommittee adopted the escapement model assuming the average recruitment scenario. The pre-fishery forecast of 78,900 tonnes in 1999 is well above the Cutoff of 21,200 tonnes. Application of the 20 percent harvest rate to the forecast resulted in a recommended yield of 15,780 tonnes.

West Coast Vancouver Island

*Background*

During the period of the reduction fishery, catches from the west coast of Vancouver Island reached nearly 70,000 tonnes in the 1958/59 season. In general, catches were in the range of 10,000 to 25,000 tonnes. During this period, annual harvests in the southern region (Area 23/24) exceeded harvests in the north (Area 25) for all but three years (51/52, 59/60, 62/63), often by large amounts. Since the roe fishery began in 1972, catches have been below the earlier levels, except from 1975 to 1978, when they ranged from 26,000 to 39,000 tonnes. In 1985 and 1986 the commercial fishery was closed along the entire west coast of Vancouver Island due to serious stock concerns. The stock subsequently rebuilt and the 1987 harvest of nearly 16,000 tonnes was the largest since 1979. However, the stock has experienced a declining trend since 1989; catches have averaged 5,400 tonnes since 1990 compared to an average harvest of 22,200 tonnes prior to 1980. Effort was restricted in 1995 and 1996 since forecast abundance was marginally above Cutoff in both years. In 1997, the forecast abundance was well above the Cutoff, and no effort restrictions were applied. The increasing trend in abundance appeared to have stalled with the 1998 stock levels similar to those observed in 1997.

*Assessment Criteria*

Stock trends derived from the two assessment models indicated a moderate stock level similar to 1997. The moderate stock level from 1995 to 1998 follows a decline in abundance from 1989 to 1994. The decline resulted from a series of years with poor recruitment, interrupted by only one year of above average recruitment in the last eight years prior to 1997. Poor recruitment was observed in 1998, with the recruiting 1995 year class accounting for 22 percent of the stock abundance. An increasing trend in spawn indices since 1996 supported the recent positive abundance trend indicated by the escapement model. The 1994 and 1995 year classes account for 60 and 22 percent of the stock, respectively.

The quality of assessment sampling and data collected was good in 1998, although FSC catch reports are incomplete. Hesquiat Harbour spawn surveys were completed. Charter skippers commented that Area 23 stocks appeared to be down, perhaps by half, from previous years. Local management staff thought that stocks were considerably weaker in Barkley Sound, but strong in Hesquiat Harbour and Sydney Inlet. Spawn was almost absent in lower Clayoquot Sound and Kyuquot.

In developing the forecast for 1999, a recruitment forecast presented in H98-4 predicted poor recruitment in 1999 (1996 year class). This prediction is based on two pieces of evidence: (1) an offshore trawl survey estimated that age 2+ herring (recruiting in 1999) will comprise about 14 percent of the spawning stock in 1999, as compared to an estimated 33 percent in 1998; and (2) an analysis of ocean temperatures and predator biomass, which were above the long term average during the first year of life of the recruiting year class. Retrospective analysis for this stock indicated that there is a 57 percent chance that a year class born in similar combinations of sea-surface temperature and hake biomass will experience poor recruitment.

Under the assumption of poor recruitment, the ASM forecast of abundance was 27,290 tonnes, while the EM forecast was 39,600 tonnes. The Subcommittee noted that the retrospective analysis suggests the ASM tends to under-forecast abundance, although performance was improved in recent years. The estimated natural mortality of 0.43 was credible. The Subcommittee adopted the escapement model assuming the poor recruitment scenario. The pre-fishery forecast of 39,600 tonnes in 1999 is well above the Cutoff of 18,800 tonnes. Application of the 20 percent harvest rate to the forecast resulted in a recommended yield of 7,920 tonnes.

Minor Stocks

The recommended yield for Area 27 is 200 tonnes, computed as 10 percent of the assessed 1998 abundance of 2000 tonnes from the escapement model. No fishery is recommended in Area 2W due to the paucity of historical and recent spawn data, biological sampling for ages, and acoustic soundings from the area. There are no dominant age classes in recent biological samples for Area 2W.

## 5. Stock Assessment Working Papers

This section presents a summary of working papers and corresponding reviews. Subcommittee discussion is recorded, along with recommendations for revision of each working paper and directions for future analyses. General recommendations from the Subcommittee appear later in the report.

### H98-1 Stock assessments for British Columbia herring in 1998 and forecasts of the potential catch in 1999.

J. Schweigert, C. Fort, R. Tanansichuk ** Accepted with revisions **

**Summary**

In this report we present stock assessments from two analytical models which have been developed explicitly for British Columbia herring: (1) a modification of the escapement model described by Schweigert and Stocker (1988); and (2) a modification of the age-structured model described by Fournier and Archibald (1982). Both models reconstruct stock abundance for the period 1951-1998 and forecast pre-spawning abundance for the 1999 season. Forecasts of upcoming run size are based on the combination of estimates of surviving repeat spawners and newly recruited spawners which are presented as poor, average, and good, based on historical recruitment levels.

**Reviewers' Comments**

Reviewer A judged the material to be well presented but commented that the escapement model lacked the statistical formalism of the age-structured model. The reviewer suggested that consideration of a spatially dis-aggregated approach might be warranted given the compromise represented by the stock definition and unaccounted for shifts in model residuals. The reviewer was confused by the use of bootstrap simulations in the determination of the Cutoff values. He suggested that a section be included to describe concerns about the modeling approaches and directions for future improvements to the assessment.

Reviewer B concluded that the assessment was generally sound. Reviewer B accepted the use of the survival estimates that combine a number of component processes (e.g. age specific natural mortality, partial recruitment, and differential sampling error by age). However, he pointed out that since the parameterization differs from conventional assessment practice, it might be prudent to focus some work on showing how the survival parameter captures variability in the component processes. The reviewer noted the lack of detail in describing the regression model used in the spawn surveys. In particular, he suggested that it might be helpful to provide an indication of uncertainty with the estimates. Reviewer B judged the stock trends to be well presented, but suggested that residuals and retrospective analyses be integrated with the stock trends. He requested more detail in the summary of the profile likelihoods to better explain the results.

Reviewer C felt that the retrospective analysis for the ASM was valuable and noted the systematic tendency for the ASM to over-estimate QCI, PR, and CC stocks, and underestimate GS and WCVI stocks. The reviewer requested a similar retrospective analysis for the EM, particularly since the EM results may be helpful in correcting the ASM bias.

The reviewer suggested that the objective of providing forecasts might be better served by the development of a forecasting model with fewer parameters but more careful attention to statistical evidence of temporal trends in parameters (*e.g.* $A_{ij}$). The current ASM is a stock reconstruction tool (a worthy objective) that may not be the best possible for forecasting.

Reviewer C favoured using the escapement model for the assessment. He requested clarification of how new age 2+ recruitment is handled in the forecasts and a presentation of the time series of estimates for the apparent survival rates, $A_{ij}$. Trends in the apparent survivals would require the use of a trend projection (*eg.* AR(1) model, short-term mean) rather than the arbitrary geometric mean estimates. Also, he suggested confirming the appropriateness of the 100 eggs/gram of herring parameter, used for converting egg calculations to biomass, with a VPA that accounts for age-specific survival differences and temporal changes in weight-at-age.

Reviewer C expressed strong concerns about the age-structured model results and suggested that they be down weighted in favour of the escapement model results. The concerns included the following:

(a) The use of the catch equation for continuous fishing is inappropriate when fishing is so strongly concentrated in time;
(b) Equations 3.1 and 3.2 are incorrect and should include time durations $t_p$ for each period over which the $M_p$ are applied (note that this issue was raised in reviews of H98-2);
(c) When data show a substantial increase in natural mortality with age, an age-independent estimate of $M_0$ (and a "plus" age group) may cause spawning stock biomass to exhibit much stronger temporal structure than is actually the case. The autocorrelation can cause various other biases in parameter estimates;
(d) The assumption of separation of age and time effects and/or age-independent fishing rates is almost never correct. The method used in the ASM may cause availability/maturation schedule changes to appear as estimated changes in recruitment rates;
(e) There was no examination of changes in vulnerability at age (*e.g.* younger fish more vulnerable causing retrospective overestimation of recruitment);
(f) There was no examination of the assumption that the tuning index (spawn) is proportional to biomass.

Reviewer C suggested separating each cohort into immature and mature components, with the immature component likely having a lower M than the migratory/mature fish. This separation may explain why M seems to increase considerably with age and why M appears to vary so much among stocks. He speculates that M might be stable, but considerable variations among stocks in maturation schedules may exist.

**Subcommittee Discussion**

There was considerable discussion of the variable, and often high, natural mortality estimates indicated by the ASM. It was noted that the variable estimates of M might be more a function of different vulnerability schedules, migration of herring stocks, or sampling biases. It was suggested that it was difficult to comment on the analysis without seeing more diagnostics (*e.g.* matrices of fishing mortalities) to examine how parameters might be interacting in the model. Because the analyses with the shorter roe herring time series gave unreasonable results, it was suggested that the model may be over-parameterized, and that results are largely dependent on assumptions. There was considerable debate on the practice of averaging the ASM and EM biomass forecasts. It was argued that the forecasts were correlated, and should not be averaged, since the EM output is the tuning index for the ASM. The Subcommittee noted that different models, even with non-independent input data, could yield insight into stock status.

There was discussion on the need to verify that the abundance index was proportional to stock size, perhaps using VPA modeling techniques. Other diagnostic steps for the ASM, such as fixing natural mortality at a reasonable value and catchability at 1, were recommended. Another step, increasing the weight on the ASM tuning index, was conducted during the meeting and produced results consistent with the EM.

The Subcommittee discussed movement of herring among assessment regions. It was argued that dependent on the role ("source" versus "sink") of various areas, different management strategies might be implied. To test this idea, it was suggested that

concurrence of year-class strengths among regions be checked. The possibility that the Strait of Georgia may be a source for recruitment to more northerly regions was discussed but not resolved. The Subcommittee discussed how to best manage small concentrations of spawn and how to protect them during the fishery. Since herring are important prey, it was pointed out that there were multi-species issues in addition to concerns about herring conservation. The Subcommittee consensus was to spread the fishing effort around the largest spawning concentrations whenever possible.

The question of whether the test fishery always covers the period of spawning, particularly in the north, was discussed by the Subcommittee in relation to possible sampling biases. The Subcommittee requested that plots of the apparent survivals ( $A_{ij}$ ) against time be examined. The strengths and weaknesses of a stock reconstruction model, such as the ASM, being used for forecasting were discussed. It was proposed that a model with a reduced parameter set be developed strictly for forecasting purposes.

In light of the decline in size-at-age described in H98-3, it was proposed that the average size-at-age numbers be replaced with the 1998 size-at-age information for the 1999 biomass forecasts. The Subcommittee concurred, and this change is reflected in forecasts provided in this Subcommittee report.

The Subcommittee agreed that there was a need to consider the available information by region. The forecast and yield recommendation for each assessment region were considered in light of retrospective patterns in the analyses, possible sampling biases as indicated from catch curve analyses, and the estimated M as indicated in the stock status information.

**Working Paper Recommendations**

1. The Subcommittee accepted the working paper subject to revisions. The revised document should provide clarification of the treatment of natural mortality noted by reviewers. Portions of the document impacted by the adoption of the 1998 size-at-age information should be updated.

**H98-2 An evaluation of the natural mortality rate used in the assessment of British Columbia herring stocks.**

J. Schweigert and R. Tanasichuk ** Accepted with revisions**

**Summary**

The estimate of the natural mortality rate assumed in conducting assessments of population abundance is a critical parameter in determining the absolute level of the stock. In most assessments, an arbitrary value of natural mortality is assumed and the assessment is conducted without good knowledge of the true mortality rate. Occasionally, it is possible to use catch curve analysis of the estimated numbers of fish at age in the population in combination with estimates of fishing effort to estimate the natural mortality rate. The natural mortality rate is also generally assumed to remain constant

over time and age in most assessments. It is unlikely that many of the assumptions about the natural mortality rate are met for the majority of stock assessments. The objectives of this study were to investigate the estimates of natural mortality rate used in recent Pacific herring assessments with a view to evaluating the impact of variation in this parameter on our perception of the abundance and trends in stock abundance. The sensitivity of abundance estimates to variation in natural mortality also provides some insight into the significance of failures to meet some of the other assumptions about the natural mortality rate on abundance levels.

**Reviewers' Comments**

The reviewers concluded that more work was required to place the results of this paper in the context of the assessment and its effects on the management of the fishery. They requested more details on the data sources and the definition of model parameters, and a full presentation of the $M_{a,i}$ calculations. Reviewer C concluded that the ASM results were suspect until the assumption of constant, age-year independent M had been tested, as well as determining whether age-year changes in M were confounded with changes in vulnerability.

Reviewers A and B both noted that the time periods allocated to instantaneous rates $M_1$, $M_2$ and $M_3$ appeared to be apply to a 1 year duration, when in fact the three periods were not equal. Reviewer A indicated that the time duration should be explicitly included in the models. This problem and the solution were also noted in a review of H98-1. Reviewer A suggested that it would be helpful to consider the assumptions and common features of both the ASM and EM to understand the divergence of the estimates. He postulated that the natural mortality rate was not equivalent to a population rate, and requested an algebraic demonstration. He suggested that Figure 5 contradicted the assumption that the proportion of age *j* available ($\lambda_{ij}$) was constant for all ages considered in the EM, noting that ages 3-11 were used on the calculations.

Reviewer B questioned the assumption that the $\lambda_{ij}$ were constant over the study period. He wondered how the fishery has changed with respect to gear and areas fished, and how the decline in size-at-age may have affected the assumption of constant availability. Reviewers B and C commented on the apparent contradiction between the results of Figure 3, which indicated poorly determined estimates, and those of Figure 6 that suggested quite precise estimates.

Both Reviewers A and B made the point that spawning biomass is not an index since the catch (an absolute quantity) is added to the estimates of spawning biomass to obtain $N_{a,i}$. This implies the catchability should be 1, however, Figure 4 indicates that catchability ranges between 0.5 and 1.5.

Reviewer C concluded that the estimates of M were more variable among stocks than general fishery experience would indicate. He suggested that natural mortality was confounded with (1) among stock differences in maturity schedules, and (2) movement of fish among areas. In the former case, stocks with later and more variable age at maturity would tend to show lower apparent M. Stock movement could take the form of increased

emigration with age from PR/QCI areas (making M look higher) into the CC area (making M look lower). If true, he suggested that plots of M against time would show lower values of $M_{a,i}$ for the CC areas several years following the production of strong year classes in the PR/QCI stocks. Because of the management implications of this hypothesis, the reviewer recommended the development of a coast-wide model that incorporates age-related exchanges among major stock areas, and a multi-stock model with dispersal exchanges to determine impacts on sustainability and long term harvest.

**Subcommittee Discussion**

The Subcommittee noted the variability in estimates of natural mortality among the five major stock assessment regions. These estimates range from 0.27 (Central Coast) to 0.59 (Strait of Georgia). The variability among stocks is more than expected for herring, and is far more variable than values reported in the fisheries literature. No analyses were conducted in the paper that allow determination of the most appropriate value of M.

The Subcommittee discussed the need to use alternate methods to corroborate the values for M (*e.g.* catch curves), and to estimate M separately for specific time periods and fisheries (*e.g.* the pre-1970 reduction fishery and the more recent roe fishery). The Subcommittee questioned the uncertainty in estimates of M and its relationship to other parameters in the model (*e.g.* catchability, fishing mortality). Considerable discussion was devoted to alternative hypotheses to explain the estimates of M. These included the possibility that movement of herring occurs from a "source" to a "sink" area. Under this scenario, emigration from an area would increase estimates of M, while immigration to an area would reduce estimates of M. It was suggested that simulation work could be conducted to test what directions and rates of stock movement were consistent with the available data. The possibility that maturity schedules have changed over time was also discussed, as was the potential for bias due to incompletely sampling the spawning run.

**Working Paper Recommendations**

1. The Subcommittee accepted the working paper subject to revisions. The revised paper is to include more detail on how time is prorated across the three periods represented by $M_1$, $M_2$, and $M_3$. Similarly, the apparent contradiction in the interpretation of the likelihood surface for M (Fig. 3) and the profile likelihoods shown in Figs. 6 and 7 should be resolved.
2. The Subcommittee recommended that simulation analyses be conducted to examine whether movement of herring among stock assessment areas is consistent with the available data.

**H98-3 Variations in size-at-age of British Columbia stocks of Pacific herring *(Clupea pallasi)* and its implications for quota recommendations and fisheries management.**

R. Tanasichuk and J. Schweigert **Accepted with revisions**

**Summary**

Length-and mass-at-age have been declining for all major B. C. herring stocks since the mid- to late-1980's. These changes are affecting the prefishery biomass forecasts. Residual analysis of forecasted mass-at-age estimates showed that there were time trends in the residuals that reflected the recent mass-at-age trends. The overestimation of mass-at-age has increased progressively since 1996. For the 1998 fishing season, mass-at-age was over-estimated by 18%. Consequently forecasts of abundance were too high. The proportion of fish available to the major (Strait of Georgia, North Coast) gillnet fisheries has declined recently due to reduced size-at-age. The biomass catchable by gillnets has declined as well. The failure to attain the quota for the 1998 North Coast gillnet fishery appears partly due to the decline in size-at-age. Size-at-age now has the potential to affect the biomass available to gillnets and consequently gear allocation policy. The decline in length-at-age has implications for the timing of gillnet fisheries. Because catchable fish currently represent a small proportion by number, and larger animals spawn first, the possibility of opening fisheries earlier than customary should be considered. A procedure for determining the catchable proportion of the pre-fishery population has been developed and is presented. This could help managers decide when gillnet fisheries should open.

**Reviewers' Comments**

The reviewers agreed that the paper drew attention to the critical topic of declines in size-at-age of B.C. herring. Reviewer A and C concluded that the suggestion to modify the gillnet fishing season to preserve gear allocation was premature. The following points were made:

(a) If the gillnet quota is a high percentage of the biomass available to the gear, and the gillnet fishery is experiencing difficulty attaining their quota, then disastrous consequences in terms of increased fishing mortality could occur.
(b) If size is decreasing, it is likely that fecundity is decreasing, so that gillnet fishing time should not be increased since the target exploitation rate may be too high. Size-fecundity effects need to be incorporated into assessment models prior to deciding whether a target harvest rate of 20 percent is safe (Reviewer C);

Reviewer A provided many suggestions for alternative analyses and pointed out several inconsistencies. He felt that the reader needed to know more about how quotas were set, target fishing levels, and how fishable biomass was defined (and hence this paper may best be embedded in the main assessment document). He concluded that there was no need to develop a new method for estimating the numbers of fish-at-age from the age composition samples since commonly accepted methods were published in the primary literature. The reviewer pointed out that catch curve analysis assumes that natural

mortality and catchability are constant, but these assumption are unlikely in the face of declining size-at-age. He raised the following criticisms of the conclusion that the quota was overestimated by 20 percent in 1998:

(a) The improvement to the estimate of stock biomass achieved by not using average weight-at-age was not demonstrated;
(b) Retrospective analyses for east coast herring often show changes of 5 to 20 percent for no clear reason except that additional information on year class strength is available;
(c) The analysis needs to be reported in terms of numbers-at-age to examine hypotheses independent of weight-at-age.

Reviewer B suggested that the discussion on condition factor be removed and that the choice of using a 90% indicator, rather than more commonly used selectivity ogive, was inappropriate. He found the presentation of the critical size parameter to be confusing and felt it lacked a strong basis. The reviewer encouraged the authors to solve the selectivity ogive to avoid confounding gear selectivity with parental size composition. He suggested that there was no need to collect gillnet samples since the size of the gillnet allocation relative to the gillnet exploitable biomass could be compared pre-season. He felt that paper should be confined to a discussion of how to anticipate the length of gillnet openings.

Reviewer C concluded that the declines in size-at-age were a serious concern. He counseled diagnostic checks for temporal trends in all assessment variables and recommended that in the presence of trends, forecasts should be based on the most recently observed values or on trend projections. The reviewer suggested an analysis based on Walford plots and von Bertalanffy growth to determine whether changes in size are due to food, competition and predation risk, or changes in metabolism.

**Subcommittee Discussion**

The Subcommittee discussed alternative explanations for the decline in size-at-age, including the possibility of a systematic drift in scale interpretation during ageing. This source of error was discounted after discussion of quality control measures used in the ageing lab. Field observation by DFO staff and industry corroborated the trend to smaller fish. The Subcommittee recommended that the most recent size-at-age information be used for generating the 1999 herring forecasts rather than the forecast size-at-age. The Subcommittee also discussed whether changes in size-at-age could be attributed to food, competition and predation risk, or changes in metabolism.

The suggestion that the decline in size-at-age was associated with a net loss in stock fecundity was discussed by the Subcommittee. It was suggested that roe mass is proportional to body mass and a decline in size-at-age could dramatically effect fecundity. For example, if large fish produce proportionally more eggs than small fish, fecundity could drop 50 percent with a 30 percent decline in size-at-age. Since the sustainable exploitation rate is a function of fecundity-at-age, a net drop in stock fecundity implies a reduction in the sustainable harvest rate. Work was cited that demonstrated herring fecundity has been reliably estimated at 200 eggs per gram of female herring, regardless

of size. Consequently, it was concluded that the fecundity of equal masses of herring is not diminished by a reduced size-at-age.

The Subcommittee discussed a reviewer's suggestion that more traditional selectivity ogives be used instead of the critical length based on the 90$^{th}$ percentile of the size distribution. It was agreed that the existing methodology in the working paper provided the necessary analysis. The problem of gear-related mortality due to passage of small size-at-age herring through gillnets was raised.

**Working Paper Recommendations**

1. The Subcommittee accepted the working paper subject to revisions. Revisions are to include Walford plot analyses as suggested by a reviewer. The discussion of condition factor is not required and should be deleted.
2. The Subcommittee recommended that the 1998 size-at-age information be used for generating the 1999 herring forecasts, rather than the forecast size-at-age. This change is reflected in the biomass forecasts included in this Subcommittee Report and the subsequent yield recommendations.
3. The Subcommittee recommended that the Herring Stock Assessment Team determine if the current 20 percent harvest rate strategy is still precautionary in light of the evidence for a decline in size-at-age. The Subcommittee requested that a working paper on the results be produced for the 1999 PSARC meeting if the findings are significant.

**H98-4 Offshore herring distribution and the 1999 recruitment forecast for the west coast of Vancouver Island stock assessment region.**

D. Ware **Accepted with revisions**

**Summary**

A multi-species mid-water trawl survey off the southwest coast of Vancouver Island (WCVI) was conducted between July 29 to August 3, 1998. Twenty tows were made to assess the species composition, research vessel catch-per-unit of effort, diet, condition factor, size and age compositions of the dominant pelagic fish species in the WCVI stock assessment region. The offshore distribution of herring in this area was fairly normal this year. The schools were found in their usual concentration centres on 40-mile Bank, Swiftsure Bank and SW Corner. Eight tows targeted on herring. Four of these tows turned out to be on immature herring schools and four on adult concentrations. Analysis of the length compositions from the adult herring samples suggests that age 2+ recruits will make up about 14 % of the west coast of Vancouver Island herring spawning stock in March 1999. Based on DFO stock assessment projections of the biomass of surviving repeat spawners, the strength of the recruiting 1996 year-class is estimated to be poor (about 2,000 to 3,000 t). A long-term DFO research program on the west coast of Vancouver indicates that herring recruitment in this region tends to be below average when ocean temperatures are warm, and the summer biomass of migratory predators (like hake and mackerel) is high. Water

temperatures were high, and the biomass of migratory hake was about average during the first year of life of the 1996 year-class. A retrospective analysis suggests that with this combination of risk factors there is a 57% chance that the 1996 year-class will be poor. Thus both the offshore survey and the risk factor forecasts suggest that the 1996 year-class is likely to be poor.

**Reviewers' Comments**

Reviewer A felt the lack of a sensitivity analysis of the assumptions made in the model was a major shortcoming of the paper, although the method appeared to be reasonable. In particular, the effects of uncertainty in the proportion of age 2+ fish, the estimates of spawning biomass, and the survival rate needed to be determined. He commented that the observed proportions of age 2+ fish were highly variable among tows and asked how the tows were judged to be representative of the population. He pointed out that weighting the proportion of age 2+ fish by CPUE would be appropriate if CPUE was directly proportional to abundance, however, this assumption was not supported in the paper. The reviewer noted that the classification of recruitment values for the forecast was based on biomass of age 2+ recruits since 1951, while those for the risk analysis were based on age 2+ recruits since 1935. Thus, the ratings of "poor", "average", and "good" were not comparable. He suggested that actual values of sea surface temperature and hake biomass could be used as predictors of age 2+ herring biomass to provide a method directly comparable to the recruitment forecast, *i.e.* the use of a contingency table was unnecessary. He also suggested that a resistant-to-outlier (robust) method be used to fit the relationships shown in Figures 6 and 7.

Reviewer B concluded that the survey methods were not adequately described. He felt that the relationship between survey and later fishery age proportions was poor and heavily influenced by a few points. The reviewer suggested that the analysis of recruitment and environment in Part II was important and the most useful part of the paper.

Reviewer C welcomed the attempt to provide "early warning" information about herring recruitment from offshore surveys but was pessimistic that sufficient data had accrued to evaluate the methods. He asked why the offshore survey data was not included directly in the age-structured analysis and noted that the compositional data appeared to be helpful in detecting weak year classes (a good property) but consistently missed strong year classes. He agreed that a relatively weak year-class would enter the WCVI fishery in 1999. Reviewer C suggested that a mixture model analysis be performed to estimate the age 2+ percentage rather than the "modal analysis" used in the paper, which he found to be unclear.

**Subcommittee Discussion**

The Subcommittee discussed the sampling methodology and the degree to which the survey tows represented the WCVI herring population. There was general concern expressed about the small sample size, although the logistics of sampling make it difficult to increase the number of survey tows. It was noted that all major herring concentrations were sampled as they were encountered. The Subcommittee discussed net avoidance

behavior by herring that can result in "topping" of the school and generally smaller fish in the catch. Suggestions were made to experiment with changing the timing of fishing operations (*e.g.* dusk) to exploit spatial aggregations of fish that differ from daylight aggregations. The Subcommittee recommended that the sampling variability of the size composition be quantified empirically and via bootstrapping to test the effects of variation in age composition on the results. It was noted that tows 3 and 5 included large 3+ age groups that contaminated the 2+ age group. Thus, the Subcommittee supported a reviewer's suggestion to assess the survey age composition using a statistical mixture model. A revised retrospective analysis of the recruit biomass forecasts using the observed pre-fishery biomass was discussed. This approach would allow the separation of variance due to the model biomass forecast. Clarification was provided that the hake biomass time-series is a proxy for the actual hake biomass over a portion of the series.

**Working Paper Recommendations**

1. The Subcommittee accepted the working paper subject to revisions. The revised paper is to address the discrepancy between the length of the recruitment biomass series used in each part of the paper. More detail is to be provided on derivation of the sea surface temperature and hake biomass time series, including figures of both series. The revised retrospective analysis suggested by the Subcommittee is to be included. The possibility of using a statistical mixture model to separate the length (age) classes should be investigated.

**H98-5 Distribution and timing of herring spawning in British Columbia.**

D. Hay and B. McCarter ** Accepted with revisions**

**Summary**

This paper examines spatial and temporal variation in herring spawn in British Columbia, from 1928 to 1998. We present summaries of temporal variation in indexes of spawn abundance for the total coast and for 6 different regions: (1) Queen Charlotte Islands (QCI), (2) Prince Rupert District (PRD), (3) Central Coast (CC), (4) Johnstone Strait (JS), (5) Strait of Georgia (SOG), and (6) West Coast of Vancouver Island (WCVI). Within the regions we distinguish between 'non-assessment' areas and 'assessment' areas. Assessment areas are the geographic units applicable to the annual stock assessments, and they make up about 55% of the total coast. In all regions the total amount of spawn has fluctuated during the last 71 years, but the pattern varies with location. Of the 5 major assessment regions, the trend in spawn deposition for the last 20 years has been to increase in the Prince Rupert District (PRD), the Central Coast (CC) and the Strait of Georgia (SOG). No trend is clear for the West Coast of Vancouver Island (WCVI) but there is a distinct trend for a long-term decline in the Queen Charlotte Islands (QCI). Similarly, there appears to be a decline in spawn indexes for most non-assessment areas in the QCI, CC, and SOG. The indexes in the Johnstone Strait, a non-assessment region, show a slight decline but the non-assessment areas of WCVI are increasing.

In general, the geographical range of spawning areas is contracting. The BC coast consists of 101 different geographic units called herring sections. The numbers of herring sections receiving spawn is lower in 1998 than in all previous records since the 1930s, when the records were known to be incomplete. In part, however, this could reflect declining survey effort. Similarly, the duration of the spawning period is becoming shorter, with later starts and early completions, in most areas. Some but not all of this trend also could be attributed to the reduction in survey effort. In the 3 major areas where spawn indexes are increasing, they are increasing substantially, so that the total coastal spawn deposition, if measured by the index presented here, is higher than in all previous assessment years. Therefore, as an approximation, we observe that spawning seems to be contracting in space and time but increasing in abundance. The trends in spawn deposition are consistent with recent changes in biomass reported in assessment documents. The assessment documents, however, do not consider the declining spatial and temporal ranges of herring, or make any comment about spawn in non-assessment areas. The reasons for the spatial and temporal changes in spawn deposition are not clear, but could be related to one or more factors including fisheries and climate change. Unfortunately some of the apparent changes could reflect declining survey efforts, particularly in the non-assessment areas.

**Reviewers' Comments**

The reviewers generally agreed that the paper provided an interesting summary of global trends in spawn data and derived indices. Reviewers A and B found that the terminology used to describe spawn was not well defined and complained that the paper did not contain sufficient detail. Both reviewers provided suggestions for improving the clarity and consistency of the presentation. Reviewer A suggested that the paper focus on trends as measured by cumulative length and the spawn index, differences between assessment and non-assessment areas, the trend in the temporal duration of spawning, and the trend in the spatial range of spawning.

Based on the indices examined in the paper, Reviewer C concluded that the results of the age-structured assessment would not differ significantly with the choice of spawn index. However, it was not clear to the reviewer that all the indices were proportional to abundance, as assumed in the age-structured assessment. Given the observed differences among the indices within an area (*e.g.* WCVI), Reviewer B also raised the question of which spawn index most closely reflects biomass.

Both Reviewer B and C commented on the issue of decreased survey intensity confounding the interpretation of spawn trends. Reviewer B suggested that indices could be positively biased by a reduction of survey effort in less important locations, and called for more details on the spawn sampling strategy. Reviewer C suggested re-allocating spawn survey effort to provide coverage to more spawn locations and times by reducing the width of spawn examined.

Both Reviewer B and C found the reduction in the number of sections with spawn, coincident with (1) an increase in the number of location within sections, and (2) a contraction of the range of spawning times, to be disturbing findings. Reviewer B noted that these signs are normally associated with a reduction in stock size and/or a reduction

in the number of local populations. Reviewer C pointed out that the current management policy based on tonnage does not consider maintenance of spatial stock structure. He suggested that future work might include the development of a plan for experimental manipulation of spawning areas to evaluate the premise that commercial spawning areas are attracting fish, thereby concentrating spawn in fewer sections. Reviewers A and B concluded that the paper did not contain sufficient evidence to support the hypotheses that fishing increases spawning activity and that more concentrated spawning is necessarily a sign of a healthy stock.

Note that Reviewer C commented on testing spawn indices for proportionality to spawn biomass. These comments are reported under Reviewer's Comments for H98-1 since they are germane to the age-structured analysis.

**Subcommittee Discussion**

Considerable discussion centered on whether changes in spawn distribution and timing reflected changes in survey sampling methodology and data handling, rather than real biological changes. For example, the working paper indicated that the number of sections having spawn has declined, although the number of locations having spawn has remained the same or increased. The discrepancy may be explained by changes in recording practices (*e.g.* Klaskish was formerly treated as one location but was separated into five locations in 1998). Also, SCUBA survey procedures often provide detailed records that may be lumped into a single record in the database. Thus, the area defined by a location may be getting smaller over time.

The increasing trend in spawn width and decreasing trend in intensity was discussed. Some of the change may be due to changes in survey methodology. For example, dive surveys are known to report wider spawns than surface surveys at a given location. Since layers of eggs are greatest in shallow depths, surface surveys should tend to report higher intensity than dive surveys. Thus, in wide spawning beds, dive survey estimates of intensity calculated by expanding over the full width of the bed should be lower than those obtained from a surface survey. However, the Subcommittee concluded it was possible that biological changes may have occurred during the period of dive surveys, resulting in increased width of spawn and decreased intensity.

The Subcommittee debated whether the reduction in the duration of spawning was real or a reflection of reduced survey coverage, and concluded that the major trends were not an artifact of the surveys. Major spawns have been surveyed adequately, although some very early and late spawn in the QCI assessment region may be missed. Survey coverage is down in non-assessment areas and is less systematic than in the past.

It was suggested that an index formed by multiplying intensity by spawn width may produce a biased index that masks a biological trend in intensity with a trend in width attributable to methodological changes. One possible means of verifying the consistency of surveys is to examine the trends at a local scale in a region where DFO staff have consistently participated in surveys (*e.g.* QCI assessment region). A key issue raised was the need to select an appropriate index that can be verified to be proportional to stock abundance.

**Working Paper Recommendations**

1. The Subcommittee accepted the working paper subject to revisions. The revisions are to focus the paper on the concentration of spawn in time and space, and to examine whether the changes in measured variables are biological or due to changes in survey methodology.

## 6. General Subcommittee Recommendations for 1998

The following general recommendations were developed as a result of review of the working papers and Subcommittee discussion:

1. The Subcommittee strongly recommended that the assumptions underlying the age-structured model should be closely examined. In particular, the Subcommittee recommended:

   (a) that the catchability and M parameters be fixed to constant values to determine the effects on the ASM output (note that an addendum was presented to the Subcommittee on September 3, 1998 which addressed this issue in part);
   (b) that the proportionality of the ASM tuning index to herring stock biomass be validated by comparison with a virtual population analysis (VPA);
   (c) that the relationship of the natural mortality parameter to other ASM parameters be investigated in light of the high variation in estimates of natural mortality (0.27 in the Central Coast to 0.59 in the Strait of Georgia);
   (d) that the hypotheses of stock migration and temporal change in maturity schedules be investigated to determine their consistency with the available data.

2. Since stock reconstruction models (*e.g.* catch-at-age models) may not provide optimal forecasting precision, the Subcommittee recommended that work be initiated on a statistical forecasting model to determine whether forecast performance can be improved.

3. The Subcommittee recommended a review of criteria for assessment of stock status prior to the 1999 PSARC meeting. The Subcommittee concluded that critical review is required for (1) the selection of the recruitment scenario, and (2) the practice of averaging forecasts from the ASM and EM. The Subcommittee supported work to guide choices among candidate assessment models and to better communicate uncertainty in stock status to managers and stakeholders.

4. Since the spawn index is critically important to the generation of scientific advice on herring resource status, there is a need to critically evaluate the consistency of the information over time and to identify the impact of changing survey methodology. The Subcommittee confirmed its support for the development of empirical estimates of variability for the spawn index. These estimates are essential to full understanding of the uncertainty in biomass estimates and stock forecasts. The Subcommittee noted

that this analysis would require collaborative input from Science and Management staff.

5. Given the decline in size-at-age described in Working Paper H98-3, the Subcommittee recommended that the most recent size-at-age information (the 1998 samples) be used in the computation of biomass forecasts pending the development of trend projections. This recommendation is reflected in the stock forecasts for 1999.

6. Annual recruitment contributes a large component (30% to 50%) to the herring spawning biomass. Thus, increased understanding of herring recruitment is key to determining the productivity of stocks and to identifying harvest opportunities. The Subcommittee recommended that offshore recruitment forecasting work for the west coast Vancouver Island herring stock continue, and that the potential for recruitment forecasting for other major stocks be investigated.

7. The Subcommittee recommended reviewing the Cutoff of 17,600 tonnes for the Central Coast assessment region. Although the Cutoff was examined in H98-1, the Subcommittee elected to reassess the Cutoff pending the results of diagnostic tests to validate the ASM.

8. Work to diagnose the poor performance of the age-structured model in the Prince Rupert District was conducted in 1998 (see H98-1), but has not fully resolved the discrepancy with the escapement model estimates. Pending the results of diagnostic work on the ASM, the Subcommittee recommended continued efforts to identify the cause(s) of the difference and to rationalize the model predictions, if possible. This work should include a retrospective analysis of the escapement model performance.

9. The Subcommittee recommended that the analysis of variability in spawn timing and location be extended to assess the likely influence of fishing effects.

10. The Subcommittee recommended that the analysis of juvenile survey data in the Strait of Georgia be repeated for the 1996 and 1997 surveys after these year classes have recruited in year 2000.

## 7. Progress on Subcommittee Recommendations for 1997

Subcommittee recommendations from 1997 are listed below (*italics*) along with progress reported at the meeting:

1. *Annual recruitment contributes a large component (30% to 50%) to the herring spawning biomass. Thus, increased understanding of herring recruitment is key to determining the productivity of stocks and to identifying harvest opportunities. The Subcommittee recommended that offshore recruitment forecasting work for the west coast Vancouver Island herring stock continue, and that the potential for recruitment forecasting for other major stocks be investigated.*

Working Paper H98-4 provided analyses that indicate recruitment of age 2+ herring to the WCVI assessment region would be poor in 1998. The Subcommittee incorporated this result into the forecast for the WCVI stock. No recruitment forecasting analyses were presented for other assessment regions.

2. *Estimates of instantaneous natural mortality (M) vary among management regions (0.267 in the Central Coast to 0.589 in the Strait of Georgia). The Subcommittee recommended that this variation be investigated (1) to determine if biological explanations exist, and (2) to assess the likely impacts of confounding among parameters in the age-structured model.*

Working Paper H98-2 examined the consequences of fixing M at various levels in the context of the ASM. There was no resolution of the discrepancies in estimated M among assessment regions.

3. *The Subcommittee recommended that the effects of systematic changes in the nature of the data over the period of the fishery be examined by using the age-structured model to fit the roe fishery data only, and contrasting the results to the fit obtained when using the entire data series.*

Working Paper H98-1 included analyses where the age-structured model was used to fit the roe fishery data only. Although the ASM converged for all stocks except the Prince Rupert District, the estimates of stock size were judged to be unrealistic. The conclusion was that the use of the 1951 to 1998 time-series was most appropriate.

4. *The Subcommittee recommended reviewing the Cutoff of 17,600 tonnes for the Central Coast management region, in light of the low value of instantaneous natural mortality estimated by the age-structured model and the relatively low long term productivity of the Central Coast stock.*

Working Paper H98-1 included a review of the Central Coast stock Cutoff of 17,600 tonnes. The paper recommended a revised Cutoff value of 14,000 tonnes based on simulation modeling of unfished equilibrium biomass. However, the existing Cutoff value was retained for 1999 pending completion of diagnostic checks and validation of the ASM.

5. *Work to diagnose the poor performance of the age-structured model in the Prince Rupert District was conducted in 1996, but has not resolved the discrepancy with the escapement model estimates. The Subcommittee recommended continued efforts to identify the cause(s) of the difference and to rationalize the model predictions, if possible. This work should include a retrospective analysis of the escapement model performance.*

Work to diagnose the poor performance of the age-structured model in the Prince Rupert District was conducted in 1998 and reported in Working Paper H98-1. The fall fishery samples were found to differ in age composition from the test fishery samples. Removal of these data resulted in greater agreement between the ASM and EM results, however a retrospective analysis using the revised data has not been conducted. A retrospective

analysis of the EM was reported in Working Paper H97-1, but was not updated for Working Paper H98-1.

6. *The Subcommittee recommended that the analysis of variability in spawn timing and location in the Strait of Georgia be extended to assess the likely influence of environmental factors, changes in biomass, pollution, and fishing effects. The Subcommittee noted that this work has application coast wide.*

The analysis of variability in spawn timing and location presented for the Strait of Georgia in 1997 has been extended to include the entire coast in Working Paper H98-5.

7. *The Subcommittee recommended that the analysis of juvenile survey data in the Strait of Georgia be repeated for the 1996 and 1997 surveys when surveyed year classes recruit in 1999 and year 2000.*

No re-analysis of the juvenile survey data is anticipated until the 1996 and 1997 recruitment data are available in year 2000.

8. *The Subcommittee confirmed its support for the development of empirical estimates of variability for the spawn index. Understanding the variability in the spawn index is essential to understanding its contribution to the uncertainty of biomass estimates and stock forecasts.*

No progress was reported on the development of empirical estimates of variability for the spawn index.

9. *The Subcommittee recommended that efforts to improve compliance with the provision of catch data continue. The Subcommittee acknowledged the efforts of those organizations that compile and submit catch data. In particular, there has been noteworthy progress by a number of First Nations fisheries programs.*

Unfortunately, recent increased compliance with the provision of catch data from First Nations, bait, and food fisheries has not continued. Data are incomplete for the CC, QCI, and WCVI assessment regions. However, landing reports for the Johnstone Strait bait fishery have improved.

10. *The Subcommittee recommended that recent gain in spawn survey coverage outside the major stock assessment regions be maintained, and that quality control auditing by DFO staff continue. The Subcommittee noted that no resources are currently identified for spawn surveys outside the major stock assessment areas.*

Some spawn survey coverage outside the major stock assessment regions was achieved in Areas 2W, 9, and 10. Late spawns that occurred after the completion of the spawn survey contract were not covered in Area 2W. Johnstone Strait was not surveyed in 1998, but survey coverage may be restored in 1999.

11. *The Subcommittee recommended that the Areas 28 and 29 be included as part of the Strait of Georgia stock assessment region in the absence of data indicating a separate stock.*

Areas 28 and 29 were included as part of the Strait of Georgia stock assessment region for the 1999 forecasts.

## 8. Partnerships with Clients

In 1995, a meeting was convened with client groups immediately following the PSARC review of herring stock assessments. This meeting, termed a "Biological Review", had the objective of fostering improved partnerships with client groups which had expressed displeasure with being excluded from the PSARC process. Science Branch staff presented herring stock assessments and forecasts for the subsequent year; discussion was confined to the biological basis for these assessments. Unfortunately, the meeting was not well attended by clients in 1995. As a result, the Biological Review was not held in 1996. Prior to the 1997 fishery, managers met with interested processors, fishers, First Nations organizations, and Provincial staff to present assessment and management information. External participants from industry and First Nations attended the PSARC Herring meeting in 1997 to assist in reviewing the assessment documents. In 1998, the review process was further expanded to include participants from seven First Nations, four industry participants, a B.C. Ministry of Fisheries participant, and DFO assessment experts from outside the Pacific Region.

Stock status reports have been completed for each of the five major herring stocks and will be updated to reflect the 1998 fishery and assessment. The Subcommittee continues to consider innovative strategies, such as video taped reviews for cable television, to disseminate information to the general public.

## 9. Other Business

### Progress Report

A progress report on the collation and analysis of historical tagging data for herring in British Columbia was tabled. These data include various tagging methods and tagging locations dating from the 1940s. A database of tagging information and graphical analyses are anticipated outcomes of the project. This project is partly funded by the HCRS.

### Stock Status Reports

The Stock Status Reports (SSRs) for the five major herring stocks will be updated to reflect the 1998 fishery and assessment. The revised SSRs will be available for general release pending approval.

**Environmental Indices**

In 1997, the Herring Subcommittee was advised of the importance of including environmental indices in stock assessment analyses. The Subcommittee was requested to identify and compile time series of stock indices, stock reconstructions, and anomalies between data sources to be utilized by researchers working with environmental data. In 1998, Working Paper H98-2 utilized sea surface temperature and a hake biomass time-series to provide auxiliary information on the probable recruitment of age 2+ herring in the WCVI assessment region.

**Selection of a New Subcommittee Chair**

The need to select a new Chair for the Herring Subcommittee in 1999 was tabled. Names of candidates should be communicated to the Chair of PSARC for consideration.

Appendix 1 PSARC Herring Working Papers for 1998

| Number | Title | Author(s) | Reviewers |
|---|---|---|---|
| H98-1 | Stock assessments for British Columbia herring in 1998 and forecasts of the potential catch in 1999 | Schweigert, J.<br>Fort, C.<br>Tanasichuk, R. | Ianelli, J.<br>Rice, J.<br>Walters, C. |
| H98-2 | An evaluation of the natural mortality rate used in the assessment of British Columbia herring stocks. | Schweigert, J.<br>Tanasichuk, R. | Gavaris, S.<br>Neilson, J.<br>Walters, C. |
| H98-3 | Variations in size-at-age of British Columbia stocks of Pacific herring (*Clupea pallasi*) and its implications for quota recommendations and fisheries management. | Tanasichuk, R.<br>Schweigert, J. | Claytor, R.<br>Nielson, J.<br>Walters, C. |
| H98-4 | Offshore herring distribution and the 1999 recruitment forecast for the west coast of Vancouver Island stock assessment region. | Ware, D.M. | Schwarz, C.<br>Stephenson, R.<br>Walters, C. |
| H98-5 | Distribution and timing of herring spawning in British Columbia | Hay, D.<br>McCarter, B. | King, J.<br>McQuinn, I.<br>Walters, C. |

Appendix 2 List of Participants for 1998 PSARC Herring Meeting

| Name | Association |
|---|---|
| Alfred, P. | Kwakiutl Territories Fisheries Commission |
| August, D. | South Coast Intertribal Fisheries Committee |
| Beamish, D. | DFO, Pacific Biological Station |
| Carpenter, Fred | Heiltsuk Tribal Council |
| Chalmers, D. | DFO, South Coast Division |
| Daniel, K. | DFO, Pacific Biological Station |
| Fradette, V. | DFO, Queen Charlotte Islands |
| Gordon, L. | DFO, Port Alberni D/O |
| Greba, L. | Kitasoo Band Council |
| Hall, D. | Nuu-chah-nulth Tribal Council |
| Hamer, L. | DFO, South Coast Division |
| Harrower, B. | B.C. Ministry of Fisheries |
| Hay, D. | DFO, Pacific Biological Station |
| Hill, B. | Tsimshian Nation |
| Jones, R. | Council of Haida Nations |
| Kronlund, R. (Subcommittee Chair) | DFO, Pacific Biological Station |
| McCarter, B. | DFO, Pacific Biological Station |
| McFarlane, S. | DFO, Pacific Biological Station |
| McQuinn, I. | DFO, I.M.L., Mont Joli |
| Midgley, P. | DFO, South Coast Division |
| Neilson, J. | DFO, St. Andrews |
| Rezansoff, B. | Gillnet, HCRS |
| Richards, L. | DFO, Pacific Biological Station |
| Safarik, E. | HCRS |
| Schweigert, J. | DFO, Pacific Biological Station |
| Stocker, M. (PSARC Chair) | DFO, Pacific Biological Station |
| Sweeting, R. | DFO, Pacific Biological Station |
| Tanasichuk, R. | DFO, Pacific Biological Station |
| Thomas, G. | DFO, South Coast Division |
| Walters, C. | University of British Columbia |
| Ware, D. | DFO, Pacific Biological Station |
| Wilson, B. | Aboriginal Vessel Owners of B.C. |
| Winther, I. | DFO, North Coast/Prince Rupert |

Appendix 3 Criteria for assessment of stock status in 1998 Queen Charlotte Islands

| Criteria | Status |
|---|---|
| 1. Data quality: | |
| (a) all catch reported | No FSC catch reported. |
| (b) all spawn surveyed | Early spawn in Louscoone hatched; incomplete survey |
| (c) consistent age composition | of 2W |
| | 2E, except Louscoone, 2W yes |
| 2. Spawn and stock trends: | |
| (a) age-structured model | Increase from 1995 continues |
| (b) escapement model | Increase from 1996 continues |
| (c) spawn indices | Spawn length increasing |
| (d) in-season echo-soundings | Peak soundings 8,300 tons |
| (e) consistent trend information | Yes |
| 3. Perception of stock status: | |
| (a) Charter skippers comments | Small size-at-age fish this year. Felt there was more spawn than in previous years, and that spawn data would indicate 20,000 tons in 2E. Stocks definitely improved. |
| (b) Management staff | Stocks improved, but not as high as 20,000 tons; spawns more numerous but smaller than previous years; estimated 30% increase in stock; smaller size-at-age. |
| 4. Recruitment trends: | |
| (a) age-structured model | Good 1994 and 1995 year classes. |
| 5. Cutoff | 10,700 |
| 6. Forecast weighted run size: | |
| (a) weighting (ASM:ESM) | 0:100 |
| (b) recruitment assumption: | |
| • Poor | • 26,490 |
| • **Average** | • **28,210 tonnes** |
| • Good | • 33,080 |
| 7. Additional information | Cumulative probability plots indicate all forecasts above Cutoff. |
| 8. Yield Recommendation | 5,642 tonnes (average recruitment assumption) |

Appendix 4 Criteria for assessment of stock status in 1998 Prince Rupert District

| Criteria | Status |
|---|---|
| 1. Data quality: | |
| (a) all catch reported | Yes |
| (b) all spawn surveyed | Yes |
| (c) consistent age composition | More small fish in Kitkatla than Big Bay |
| 2. Spawn and stock trends: | |
| (a) age-structured model | Increase from 1997 |
| (b) escapement model | Decrease from 1997 |
| (c) spawn indices | Down |
| (d) in-season echo-soundings | Area 3&4 peak soundings 8,000 tons, Kitkatla Inlet >3,400 tons |
| (e) consistent trend information | No |
| 3. Perception of stock status: | |
| (a) charter skippers comments | Area 3&4 stocks down considerably from last year, but Kitkatla looked a lot better than previous years |
| (b) management staff | Kitkatla had best spawn seen in years |
| 4. Recruitment trends: | |
| (a) age-structured model | Good 1993 and average 1995 year classes |
| 5. Cutoff | 12,100 |
| 6. Forecast weighted run size: | |
| (a) weighting (ASM:ESM) | 0:100 |
| (b) recruitment assumption: | |
| • Poor | • 22,020 |
| • **Average** | • **24,420 tonnes** |
| • Good | • 32,400 |
| 7. Additional information | Cumulative probability plots indicate all forecasts above Cutoff. |
| 8. Yield Recommendation | 4,884 tonnes (average recruitment assumption) |

Appendix 5 Criteria for assessment of stock status in 1998 Central Coast

| Criteria | Status |
|---|---|
| 1. Data quality: | |
| (a) all catch reported | FSC catch incomplete (Heltsiuk FSC catch reported) |
| (a) all spawn surveyed | Yes, no survey of late spawns in Burke Channel (outside assessement area) |
| (c) consistent age composition | Yes |
| Spawn and stock trends: | |
| (a) age-structured model | Strong increase from 1996 continues |
| (b) escapement model | Strong increase from 1996 continues |
| (b) spawn indices | Increase since 1996 continues |
| (c) in-season echo-soundings | Peak sounding: Area 6 10,000 tons, Area 7 28,000 tons, Kwakshua Channel 3,000 tons, Namu to Fish Egg 2,000 tons |
| (e) consistent trend information | Yes |
| 3. Perception of stock status: | |
| (a) charter skippers comments | Felt stocks in the area were healthy, although perhaps a bit less than in 1997, Spiller Channel had good spawn. |
| (b) management staff | Stocks were generally healthy. Spawns occurred in more areas than in recent years. |
| 4. Recruitment trends: | |
| (a) age-structured model | Good 1994 and 1995 year classes |
| 5. Cutoff | 17,600 |
| 6. Forecast weighted run size: | |
| (a) weighting (ASM:ESM) | 0:100 |
| (b) recruitment assumption: | |
| • Poor | • 41,000 |
| • **Average** | • **43,430 tonnes** |
| • Good | • 53,010 |
| 7. Additional information | Cumulative probability plots indicate all forecasts above Cutoff. |
| 8. Yield Recommendation | 8,686 tonnes (average recruitment assumption) |

Appendix 6 Criteria for assessment of stock status in 1998 Strait of Georgia

| Criteria | Status |
|---|---|
| 1. Data quality: | |
| (a) all catch reported | FSC catch is reported. |
| (b) all spawn surveyed | Yes |
| (c) consistent age composition | Yes, except area 15 where more age 2+ fish were observed |
| 2. Spawn and stock trends: | |
| (a) age-structured model | Continued slight decline from 1996 |
| (b) escapement model | Slight increase from 1997 |
| (c) spawn indices | Increase from 1997 |
| (d) in-season echo-soundings | Peak soundings 117,000 tons |
| (e) consistent trend information | No |
| 3. Perception of stock status: | |
| (a) charter skippers comments | Stocks were impressive, but size of fish was not. |
| (b) management staff | Gulf continues to show very strong returns, but staff were concerned about the catchable size of gillnet herring in 1998. Spawning distribution was very good, with spawning spread throughout the Gulf. |
| 4. Recruitment trends: | |
| (a) age-structured model | Average to good 1993 to 1995 year classes |
| 5. Cutoff | 21,200 |
| 6. Forecast weighted run size: | |
| (a) weighting (ASM:ESM) | 0:100 |
| (b) recruitment assumption: | |
| • Poor | • 65,640 |
| • **Average** | • **78,900 tonnes** |
| • Good | • 98,690 |
| 7. Additional information | Continued northward shift in spawning. Cumulative probability plots indicate all forecasts above Cutoff. |
| 8. Yield Recommendation | 15,780 tonnes (average recruitment assumption) |

Appendix 7 Criteria for assessment of stock status in 1998 West Coast Vancouver Island

| Criteria | Status |
|---|---|
| 1. Data quality: | |
| (a) all catch reported | FSC catch reports are incomplete |
| (a) all spawn surveyed | Complete survey of Hesquiat, small early spawns in Barkley hatched but were not surveyed. |
| (c) consistent age composition | Yes |
| 2. Spawn and stock trends: | |
| (a) age-structured model | Stock level similar to 1997 |
| (b) escapement model | Stock level similar to 1997 |
| (c) Spawn indices | Decline |
| (d) in-season echo-soundings | Peak soundings: Area 23 9,900 tons, Area 24 4,500 tons, Area 25 3,000-4,000 tons. Stocks in Esperanza and Nuchatlitz seemed to be average, no fish seen in Nootka |
| (e) consistent trend information | Yes |
| 3. Perception of stock status: | |
| (a) charter skippers comments | Area 23 stocks down from previous years, some estimated only half as much. |
| (b) management staff | Stocks were considerably weaker in Barkley, quite strong in Hesquiat Harbour and Sydney Inlet, and almost non-existent in lower Clayoquot. No spawn in Kyuquot. Winter Harbour appeared the same. |
| 4. Recruitment trends: | |
| (a) age-structured model | Good 1994 year class followed by poor 1995 year class |
| 5. Cutoff | 18,800 |
| 6. Forecast weighted run size: | |
| (a) weighting (ASM:ESM) | 0:100 |
| (b) recruitment assumption: | |
| • **Poor** | • **39,600 tonnes** |
| • Average | • 45,130 |
| • Good | • 58,930 |
| 7. Additional information | Science staff note shift in spawn from Barkley Sound to Hesquiat. Cumulative probability plots indicate all forecasts above Cutoff. Offshore survey (H98-2) indicates poor-average 1996 year class. |
| 8. Yield Recommendation | 7,920 tonnes (poor recruitment assumption) |